

REPORT 1037

GENERAL METHOD AND THERMODYNAMIC TABLES FOR COMPUTATION OF EQUILIBRIUM COMPOSITION AND TEMPERATURE OF CHEMICAL REACTIONS¹

By VEARL N. HUFF, SANFORD GORDON, and VIRGINIA E. MORRELL

SUMMARY

A rapidly convergent successive approximation process is described that simultaneously determines both composition and temperature resulting from a chemical reaction. This method is suitable for use with any set of reactants over the complete range of mixture ratios as long as the products of reaction are ideal gases. An approximate treatment of limited amounts of liquids and solids is also included. This method is particularly suited to problems having a large number of products of reaction and to problems that require determination of such properties as specific heat or velocity of sound of a dissociating mixture.

The method presented is applicable to a wide variety of problems that include (1) combustion at constant pressure or volume; and (2) isentropic expansion to an assigned pressure, temperature, or Mach number. Tables of thermodynamic functions needed with this method are included for 42 substances for convenience in numerical computations.

INTRODUCTION

The theoretical performance of propulsion systems having high combustion temperatures can be calculated on the assumption that chemical equilibrium exists among the products of reaction. The equilibrium composition and the temperature for a system of N products of reaction are determined by the simultaneous solution of at least $N+1$ equations involving dissociation, mass balance, and energy or entropy balance. This calculation becomes increasingly difficult as N increases.

Numerous methods for solving these equations may be found in the literature that provide a successive approximation or trial-and-error process for determining the composition at an assumed temperature and pressure. Examples of these methods are found in references 1 to 4. When it is desired to find the temperature of a system in equilibrium, with a parameter such as entropy or enthalpy assigned, the composition is usually computed at a sequence of temperatures that either converge to the correct temperature or are spaced to permit interpolation to obtain the correct temperature.

A rapidly convergent successive approximation process that determines composition at an assigned temperature or that simultaneously determines both composition and temperature for assigned values of another parameter, such as enthalpy or entropy, was developed at the NACA Lewis laboratory during 1948 and is presented herein. This proc-

ess also permits computation of the partial derivatives required to compute such thermodynamic properties as specific heat and velocity of sound corresponding to chemical equilibrium. The equations are derived that are required for solution of the following cases: (1) combustion at constant pressure or volume; and (2) isentropic expansion to an assigned pressure, temperature, or Mach number. Examples are given for (1) constant-pressure adiabatic combustion; (2) isentropic expansion to an assigned pressure; and (3) isentropic expansion to an assigned Mach number.

This method is particularly suitable for problems having a large number of products of reaction and for problems that require determination of partial derivatives. Although it is possible, at least in special cases, to devise a procedure that involves less numerical computation, the method presented is applicable in a wide variety of cases and its numerical application to a given process is always simple and essentially the same for all reactions.

Tables of thermodynamic functions are needed for computing equilibrium compositions and temperature of chemical reactions. Tables containing the functions specific heat at constant pressure C_p^o , sensible enthalpy $H_T^o - H_0^o$, and molar entropy S_T^o exist for at least part of the desired temperature range for most of the substances of interest in the analysis of aircraft-propulsion systems. Several special functions are required for convenient use with the method described herein; tables were therefore prepared, from January to June 1949, that contain, in addition to C_p^o , $H_T^o - H_0^o$, and S_T^o , assigned values of enthalpy H_T^o and values of $\log K$ and $\frac{-\Delta H^o}{RT}$ (logarithm of equilibrium constant and enthalpy change divided by gas constant times temperature, respectively, for reaction of formation of a substance from its elements in atomic gas state).

The data selected from various sources or computed by the NACA have been smoothed, interpolated to every 100°, and extended to 6000° K. A high degree of self-consistency has been maintained in the temperature range from 1000° to 6000° K by computing from specific-heat data the values of the other functions and retaining, in general, more decimal places than are significant. Interpolation formulas are given that permit computation of self-consistent values for all the functions at any temperature between 1000° and 6000° K.

¹ Supersedes NACA TN 2113, "General Method for Computation of Equilibrium Composition and Temperature of Chemical Reactions" by Vearl N. Huff and Virginia E. Morrell, 1950, and NACA TN 2161, "Tables of Thermodynamic Functions for Analysis of Aircraft-Propulsion Systems" by Vearl N. Huff and Sanford Gordon, 1950.

GENERAL METHOD

The thermodynamic state following a specific process, such as combustion at constant pressure, can be determined from an appropriate combination of the following equations: (a) dissociative equilibrium; (b) conservation of mass; (c) conservation of energy; (d) pressure; and (e) entropy. Equations (a) and (b) are used to specify chemical equilibrium and, when used with any two of the remaining equations, define a process.

The successive approximation procedure presented herein for finding the simultaneous solution of a specific combination of equations (a) to (e) consists of the following steps:

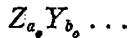
(1) Estimates of composition and temperature are made and used in simple equations to compute the values of error parameters, which indicate inconsistency among the estimates of composition and temperature. (These estimates need not be based on previous experience, but for rapid convergence it is desirable that they be close to the final values.)

(2) A set of linear simultaneous correction equations is given that determine a new composition and a new temperature.

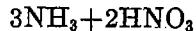
(3) The new composition is used to compute new values of the error parameters and step (2) is repeated until the desired accuracy is obtained.

EQUATIONS FOR DISSOCIATION, MASS, PRESSURE, AND VOLUME

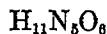
The substances entering a reaction process will be designated the reactants and can be represented by the equivalent formula



where the subscripts a_0, b_0, \dots are proportional to the total number of atoms of the elements Z, Y, \dots , respectively, contained in a quantity of the entering substance at the initial conditions. (A complete list of symbols is included in appendix A.) For example, the reactants for a rocket combustion process using 3 moles of ammonia (NH_3) for fuel and 2 moles of nitric acid (HNO_3) for an oxidant are

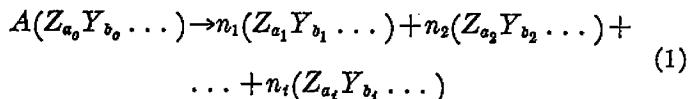


An equivalent formula would be



where the atoms hydrogen, nitrogen, and oxygen, may be represented by Z, Y , and X , respectively, and 11, 5, and 6 by a_0, b_0 , and c_0 , respectively. The weight of the equivalent formula M_r can be computed in the usual way and would be 177.128. (If desirable, the quantity of substance in the equivalent formula may be chosen to correspond to a specified value of M_r . For example, if M_r is to be one gram, the preceding values would be divided by 177.128.)

The reaction under consideration can be written



where n_i is the number of moles of the i th molecule or atom. The subscripts a_i, b_i, \dots , which can take on only positive

integral values or zero, denote the number of Z, Y, \dots atoms in the i th molecule. For example, if Z, Y , and X again represent hydrogen, nitrogen, and oxygen, respectively, the values of a_i, b_i , and c_i for a water molecule H_2O would be 2, 0, and 1, respectively. It is assumed that the products of reaction are contained by a volume V numerically equal to the gas constant R times the absolute temperature T so that for ideal gases

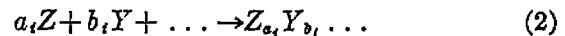
$$p_i = n_i$$

During the solution of the problem, it is necessary to determine the number of formula weights of the reactants A that are required to balance the reaction given by equation (1). Products of reaction in the gas phase are assumed to be ideal gases that form ideal mixtures and each condensed phase is assumed to have a partial pressure of zero, even when finely divided and suspended in the gas. For solids and liquids therefore

$$p_i = 0$$

As an approximation, the following assumptions are also made: Each condensed product is insoluble in all others; the fugacity of each condensed phase is equal to 1 atmosphere; the total volume occupied by the liquids and solids is negligible with respect to the volume occupied by the gases; and the liquid and solid particles have the same temperature and flow velocity as the gases.

Dissociation equations.—For simplicity of nomenclature and presentation, the equations for dissociation can be written in terms of the atomic gas as



The corresponding equation for the equilibrium constant K_t of gaseous molecules is

$$K_t = \frac{p_i}{p_z p_y \dots} \quad (3)$$

For liquid or solid molecules, assuming the fugacity of each condensed phase is equal to 1 atmosphere,

$$K_t = \frac{1}{p_z p_y \dots} \quad (4)$$

where p_z, p_y, \dots are the partial pressures of the Z, Y, \dots atoms in equation (1), respectively. The equilibrium constants can also be expressed in terms of the free-energy changes (ΔF_r°), across the dissociation reactions represented by equation (2) or

$$\ln K_t = \left(\frac{-\Delta F_r^\circ}{RT} \right)_t \quad (5)$$

Because the trial composition may not correspond to that at chemical equilibrium, variables δ_i are conveniently defined so that for gaseous molecules (logarithms to the base 10 are used)

$$\delta_i = \log p_i - a_i \log p_z - b_i \log p_y - \dots - \log K_t \quad (6)$$

and for liquid or solid molecules

$$\delta_i = -a_i \log p_z - b_i \log p_r - \dots - \log K_i \quad (7)$$

where K_i is defined by equation (5). The value of each δ_i must approach zero when the solution to the problem is found. Application of equation (6) or (7) to each product of reaction will result in one equation for each molecule considered since for atoms, δ_i is identically zero.

Mass-balance equations.—A mass-balance equation stating the conservation of atomic type can be written for each chemical element present.

$$\begin{aligned} a &= \frac{1}{A} \sum_i a_i n_i \\ b &= \frac{1}{A} \sum_i b_i n_i \\ \dots &= \dots \end{aligned} \quad (8)$$

where a, b, \dots are the number of gram atoms of substance Z, Y, \dots per equivalent formula required to form the products of reaction. A trial composition generally leads to values of a, b, \dots that differ from the desired values of a_0, b_0, \dots but the difference will vanish when the correct composition is found.

Total-pressure equation.—The total pressure P is the sum of the partial pressures

$$P = \sum_i p_i \quad (9)$$

For a process with an assigned pressure, the value of P must approach the assigned value P_0 as the solution of the problem is found.

Constant volume.—For processes that occur at constant volume, the density of the mixture is constant. The density ρ is defined as

$$\rho = \frac{AM_r}{V} = \frac{AM_r}{RT} \quad (10)$$

For a reaction process with an assigned density, the value of ρ must approach the assigned value ρ_0 as the solution of the problem is found.

COMBUSTION AT CONSTANT PRESSURE

For given initial conditions, the temperature and the composition following a combustion process are to be found. When chemical energy is included in the enthalpy of each substance, the enthalpy of the products of reaction following an adiabatic combustion must be equal to the enthalpy of the reactants at the initial conditions. An arbitrary base may be adopted for assigning absolute values to the enthalpy of various substances because only differences are measurable. The base used to compute values of enthalpy H_T^o was selected to produce positive values for all molecular types entering a combustion process in order to avoid a possible source of difficulty that might occur in the recommended

method of adjustment when a logarithm of a negative number (or zero) might be required.

Enthalpy of fuel and oxidant.—The enthalpy at initial conditions of the amount of fuel and oxidant corresponding to the equivalent formula $Z_{a_0} Y_{b_0} \dots$ is denoted by h_0 and is given by the expression

$$h_0 = n_f (H_T^o)_f + n_g (H_T^o)_g \quad (11)$$

where n_f and n_g are the number of moles of fuel and oxidant, respectively, corresponding to the equivalent formula $Z_{a_0} Y_{b_0} \dots$ and $(H_T^o)_f$ and $(H_T^o)_g$ are the molar enthalpies of the fuel and the oxidant, respectively, at the initial conditions. The molar enthalpy H_T^o is defined by the equation

$$H_T^o = \int_0^T C_p dT + H_0^o$$

where C_p is the molar specific heat at constant pressure, and H_0^o is the chemical energy of the substance at a temperature of $0^\circ K$. Values of H_T^o for several fuels and oxidants are presented with the tables of thermodynamic functions.

Enthalpy of products of reaction.—The enthalpy of the products of reaction per equivalent formula can be conveniently represented by a variable h that is given by the equation

$$h = \frac{1}{A} \sum_i (H_T^o)_i n_i \quad (12)$$

When enthalpy is assigned, (for example, with adiabatic combustion) the difference between h and the assigned value h_0 must vanish when the correct values of n_i, A , and T are found. If heat were lost (nonadiabatic combustion), the value of h_0 would be accordingly reduced.

Equations for constant-pressure combustion.—The equations defining the constant-pressure combustion are:

Type	Number of equations
Dissociative equilibrium	1 for each molecular type.
Conservation of mass	1 for each chemical element.
Constant pressure	1.
Conservation of energy	1.

These equations are to be solved simultaneously for the variables n_i, A , and T ($p_i = n_i$ for gases).

Correction equations.—Since the preceding equations are not all linear, it is usually not feasible to find a direct solution. The Newton-Raphson method for solving nonlinear simultaneous equations (reference 5) is well suited to this type of computation. This method can be illustrated by a simple example. If Q_1 and Q_2 are functions of q and r ,

$$Q_1 = f_1(q, r)$$

$$Q_2 = f_2(q, r)$$

By taking estimated values, for example q_0 and r_0 , each function may be expanded in a Taylor's series about the point (q_0, r_0) and when derivatives of higher order than the first are neglected

$$\Delta Q_1 = \frac{\partial Q_1}{\partial q} \Delta q + \frac{\partial Q_1}{\partial r} \Delta r$$

$$\Delta Q_2 = \frac{\partial Q_2}{\partial q} \Delta q + \frac{\partial Q_2}{\partial r} \Delta r$$

The desired changes ΔQ_1 and ΔQ_2 can be computed; if the partial derivatives can be numerically evaluated, solving for the approximate changes in q and r to effect simultaneously the desired changes in both Q_1 and Q_2 is comparatively simple because the equations are linear.

If each of the functions δ_t , a , b , \dots , P , and h given by equations (6) to (9) and (12) is expanded in a Taylor's series about an estimated set of values of the variables and terms involving derivatives of order higher than the first are neglected, the following set of simultaneous linear correction equations results:

For gaseous products

$$x_t - a_t x_z - b_t x_y - \dots - q_t x_r = -\delta_t \quad (13)$$

For solid or liquid products

$$-a_t x_z - b_t x_y - \dots - q_t x_r = -\delta_t \quad (14)$$

For all products

$$\sum_t a_t n_t x_t - A a x_A = \delta_a$$

$$\sum_t b_t n_t x_t - A b x_A = \delta_b$$

$\dots = \dots$

$$\sum_t p_t x_t = \delta_p$$

$$\sum_t h'_t x_t - A h x_A + T C' x_r = \delta_h \quad (17)$$

where the correction variables and the error parameters may be defined in the logarithmic form

$$x_t = \Delta \log n_t = \Delta \log p_t$$

$x_z, x_y, \dots = x_t$ for atoms

$$x_A = \Delta \log A$$

$$x_r = \Delta \log T$$

$$-\delta_t = \Delta \delta_t$$

$$\delta_a = A a \log \frac{a_o}{a}$$

$$\delta_b = A b \log \frac{b_o}{b}$$

$\dots = \dots$

$$\delta_p = P \log \frac{P_o}{P}$$

$$\delta_h = A h \log \frac{h_o}{h}$$

and where $q_t = \left(\frac{\Delta H}{RT} \right)_t = \frac{\partial \log K_t}{\partial \log T}$, $h'_t = (H^\circ)_t n_t$, $C' = \sum_t (C^\circ)_t n_t$.

The solution to the set of simultaneous equations relates the value of the r^{th} estimate to the $(r+1)^{\text{th}}$ estimate as follows:

$$\begin{aligned} \log (n_t)_{r+1} &= \log (n_t)_r + x_t \\ \log (A)_{r+1} &= \log (A)_r + x_A \\ \log (T)_{r+1} &= \log (T)_r + x_r \end{aligned} \quad (18)$$

The expansion in the Taylor's series has been carried out in the logarithmic form because this form has been found to result in rapid convergence over a wide range of conditions and avoids the possibility of computing negative partial pressures. If the expansion is carried out in powers of $x_t = \frac{\Delta n_t}{n_t}$ or $x_t = n_t \Delta \left(\frac{1}{n_t} \right)$ the same correction equations result as for the logarithmic variables except for the definitions of the correction variables and error parameters. Quite satisfactory results have been obtained by taking $x_t = \frac{\Delta n_t}{n_t}$ when x_t is positive and $x_t = n_t \Delta \left(\frac{1}{n_t} \right)$ when x_t is negative.

MATRIX CONSTRUCTION AND REDUCTION

A coefficient matrix is a scheme of detached coefficients of a set of linear equations that are to be solved simultaneously. An augmented matrix is identical to a coefficient matrix except that the constants are included. Equations (13) to (17) constitute such a set of equations for the simultaneous determination of the variables x_t , x_A , and x_r .

Construction.—Because of the large number of zeros occurring in the matrix, a considerable saving in effort can be made by proper arrangement of the order of the rows and the columns. The following arrangement provides a partly symmetrical matrix that has been found to be among the easiest to evaluate as long as the products of reaction are principally gaseous and the dissociation constants are expressed in terms of the atomic species:

The order of the columns should be—

- (a) x_t of gaseous molecules
- (b) x_t of atoms
- (c) x_t of liquid and solid products
- (d) x_A
- (e) x_r
- (f) Constant terms of equations

The order of the rows is—

- (a) Dissociation equations in same order as gaseous molecules in columns
- (b) Mass-balance equations in order of atoms in columns
- (c) Dissociation equations for solid and liquid products in same order as solid and liquid in columns
- (d) Total-pressure equation
- (e) Heat-balance equation in combustion calculation

The augmented matrix of equations (13) to (17) arranged in this recommended order is shown in figure 1.

Equation	Gaseous molecules			Atoms			Solids or Liquids				
	x_1	x_2	...	x_x	x_y	...	...	x_N	x_A	x_T	Const
(13)	1	0	0	- a_1	- b_1	...	0	0	0	- q_1	- δ_1
	0	1	0	- a_2	- b_2	...	0	0	0	- q_2	- δ_2
	0	0	...	...	...	...	0	0	0	...	...
a	$a_1 n_1$	$a_2 n_2$	...	n_x	0	0	-	$a_N n_N$	- Aa	0	δ_a
b	$b_1 n_1$	$b_2 n_2$	...	0	n_T	0	-	$b_N n_N$	- Ab	0	δ_b
...	...	...	...	0	0	...	-	...	0	0	...
...	0	0	0	...	...	0	0	0	0	...	...
N	0	0	0	a_N	b_N	...	0	0	0	q_N	δ_N
p	p_1	p_2	...	p_x	p_T	0	0	0	0	0	δ_p
h	h_1'	h_2'	...	h_x'	h_T'	...	-	h_N'	- Ah	TC'	δ_h

FIGURE 1.—General matrix of correction equations for adiabatic combustion at assigned pressure. Equation (13), dissociation of gaseous molecules; equation (15), mass balance; equation (14), dissociation of solids or liquids; equation (16), pressure; equation (17), heat balance.

Solution.—One of the best methods of solving simultaneous linear equations is given by Crout (reference 6). With this method, an auxiliary matrix is constructed from an original augmented matrix by a simple routine. This auxiliary matrix is of the order equal to the original matrix. The solution for the set of equations can be obtained by a process of back substitution in the auxiliary matrix.

For convenience, the order of the matrix is reduced before the Crout method is applied. A matrix arranged as recommended can be partitioned so that a unit matrix $[U_m]$ of the order (m, m) appears in the upper left corner, where m is equal to the number of types of gaseous molecule. The original augmented matrix can then be written

$$\begin{bmatrix} U_m & | & \alpha_1 \\ \alpha_2 & | & \alpha_3 \end{bmatrix} \quad (19)$$

When the Crout method is applied to the original augmented matrix, the Crout auxiliary matrix can be expressed as

$$\begin{bmatrix} U_m & | & \alpha_1 \\ \alpha_2 & | & \alpha_4 \end{bmatrix} \quad (20)$$

where $[U_m]$, $[\alpha_1]$, and $[\alpha_2]$ are identical to the corresponding submatrices of the original matrix. By observing the operations involved in the construction of the Crout auxiliary matrix, $[\alpha_4]$ is shown to be identical to the auxiliary matrix of the augmented matrix $[\alpha_5]$ defined by

$$[\alpha_5] = [\alpha_3] - [\alpha_2][\alpha_1] \quad (21)$$

For computation, equation (21) is written

$$[\alpha_5] = [\alpha_2][\alpha_3] \begin{bmatrix} -\alpha_1 \\ U_k \end{bmatrix} \quad (22)$$

where $[U_k]$ is a unit matrix of order equal to the number of columns of $[\alpha_1]$. The numerical solution is then obtained by carrying out the matrix multiplication indicated in equation (22) to find $[\alpha_5]$. The Crout auxiliary matrix $[\alpha_4]$

Gaseous molecules			Atoms			Solids or Liquids					
x_1	x_2	...	x_x	x_y	...	...	x_N	x_A	x_T	Const
$a_1 n_1$	$a_2 n_2$	...	n_x	0	0	-	$a_N n_N$	- Aa	0	δ_a
$b_1 n_1$	$b_2 n_2$	...	0	n_T	0	-	$b_N n_N$	- Ab	0	δ_b
...	...	...	0	0	...	-	0	0	0	...
...	...	...	0	0	...	-	0	0	0	...
N	0	0	0	a_N	b_N	...	0	0	0	q_N	δ_N
p	p_1	p_2	...	p_x	p_T	0	0	0	0	0	δ_p
h	h_1'	h_2'	...	h_x'	h_T'	...	-	h_N'	- Ah	TC'	δ_h

(a) Submatrix $[\alpha_2|\alpha_3]$ taken from lower portion of figure 1.

a	a_1	a_2	...	1	0	0	0	0	0	0	0
b	b_1	b_2	...	0	1	0	0	0	0	0	0
...	...	...	...	0	0	0	0	0	0	0	0
...	0	0	0	0	0	0	0	0	0	0	0
N	0	0	0	0	0	0	0	0	1	0	0
...	0	0	0	0	0	0	0	0	0	1	0
q	q_1	q_2	...	0	0	0	0	0	0	1	0
δ	δ_1	δ_2	...	0	0	0	0	0	0	0	1

(b) Submatrix $\begin{bmatrix} -\alpha_1 \\ U_k \end{bmatrix}$ transposed ($-\begin{bmatrix} \alpha_1 \\ U_k \end{bmatrix}$) taken from figure 1.

FIGURE 2.—General form of submatrices of correction equations for adiabatic combustion at assigned pressure.

is constructed from $[\alpha_5]$. The values of the variables x_{m+1} , ..., x_{N+2} are found from $[\alpha_1]$ by the process of back substitution given by Crout. The values of the remaining variables are found by the matrix equation

$$\begin{bmatrix} x_1 \\ \vdots \\ x_m \end{bmatrix} = -[\alpha_1] \begin{bmatrix} x_{m+1} \\ \vdots \\ x_{N+2} \\ -1 \end{bmatrix} \quad (23)$$

For illustration, the submatrices $[\alpha_1]$, $[\alpha_2]$, and $[\alpha_3]$ were taken from figure 1 and used to construct figure 2. The submatrix $[\alpha_2|\alpha_3]$ corresponds to equations (15), (14), (16), and (17) and is shown in figure 2 (a). The transposed matrix of $\begin{bmatrix} -\alpha_1 \\ U_k \end{bmatrix}$ is shown in figure 2 (b); that is, the columns have been tabulated as rows with the first column at the top.

COMBUSTION AT CONSTANT VOLUME

The procedure given for finding the composition and the temperature of a combustion process at constant pressure can be applied to combustion at constant volume with the following changes:

(a) The correction equation for pressure is replaced by a correction equation for density obtained from equation (10)

$$x_A - x_T = \log \frac{\rho_0}{\rho} \quad (24)$$

(b) The correction equation for conservation of energy must be written in terms of internal energy E_T° and thus becomes

$$\sum_i (E_T^\circ)_i n_i x_i - A e x_A + T \sum_i (C_v^\circ)_i n_i x_T = A e \log \frac{e_0}{e} \quad (25)$$

where

$$e = \frac{1}{A} \sum_i (E_T^\circ)_i n_i$$

e_0 is the assigned internal energy per equivalent formula at initial given conditions, and C_v° is the molar specific heat at constant volume. Substitution of these two equations in the matrix of figures 1 and 2 (a) will permit the composition and the temperature to be found for assigned values of density and internal energy. The application of this method to constant-volume combustion, which, for example, is involved in reciprocating engines and pulse-jet engines, has not been made at the Lewis laboratory.

ISENTROPIC EXPANSION TO ASSIGNED PRESSURE OR TEMPERATURE

Assigned pressure.—The calculation of temperature and equilibrium composition of the products of reaction following isentropic expansion to a fixed pressure involves the simultaneous solution of dissociation, conservation-of-mass, pressure, and entropy-balance equations.

For the reaction of equation (1), the dissociation, conservation of mass, and pressure equations (6) to (9) can again be applied. For the conditions following an isentropic expansion, the entropy s of the products of combustion per equivalent formula after expansion must be equal to the entropy s_0 of the products of combustion per equivalent formula before expansion.

$$s_0 = \left\{ \frac{1}{A} \sum_i [n_i (S_T^\circ)_i - R p_i \ln p_i] \right\}_{\text{combustion conditions}} \quad (26)$$

where $(S_T^\circ)_i$ is the absolute entropy of the product i at standard conditions. This formula is applicable to ideal solids and liquids, assuming $p_i = 0$, as long as their volume is negligible. After the expansion takes place, the entropy per equivalent formula is given by the expression

$$s = \left\{ \frac{1}{A} \sum_i [n_i (S_T^\circ)_i - R p_i \ln p_i] \right\}_{\text{exit conditions}} \quad (27)$$

Whereas equation (26) is, of course, evaluated at combustion-chamber temperature and pressure, equation (27) is evaluated for exit temperature and pressure. As the solution of the problem is found by successive adjustment of estimated quantities, the value of s approaches s_0 .

In the adjustment of the values of n_i , A , and T , the correction equations (13) to (16), which have been derived from equations (6) to (9), can be applied. In addition, the fol-

lowing correction equation for entropy can be written from equation (27):

$$\sum_i s_i' x_i - A s x_A + C' x_T = \delta_s \quad (28)$$

where

$$\delta_s = A s \log \frac{s_0}{s}$$

$$s_i' = (S_T^\circ)_i n_i - R p_i (1 + \ln p_i)$$

The row matrix of equation (28) shown in figure 3 may be substituted in place of the \mathbf{h} rows of figures 1 and 2 (a) and the computation carried out as in the combustion calculation.

Equation											
\mathbf{s}											
(28)											
	s_1'	s_2'	\dots	s_x'	s_y'	\dots	\dots	$s_{N'}$	$-A s$	C'	\mathbf{i}_s

FIGURE 3.—Row matrix to be substituted in place of \mathbf{h} row in figure 1 and in figure 2 (a) for isentropic expansion to assigned pressure. Equation (28), entropy balance.

Assigned temperature.—For the computation of data for enthalpy-entropy diagrams and for other practical computations, it is often necessary to find the exit pressure and composition as a function of exit temperature. The procedure required is the same as that described for isentropic expansion to an assigned pressure except that, in addition to substituting the \mathbf{s} row in place of the \mathbf{h} row, the pressure equation (\mathbf{p} row) and the temperature column (x_T) are dropped from the matrix of figure 1; accordingly, the \mathbf{p} row and x_T column are dropped from figure 2 (a) and the \mathbf{q} row from figure 2 (b).

ISENTROPIC EXPANSION TO LOCAL VELOCITY OF SOUND

The theoretical velocity of sound that includes the effect of dissociation can be computed at any point in a nozzle with a modification of the matrix previously derived to obtain the correction quantities.

Velocity of sound.—The velocity of sound u can be defined as

$$u^* = \left(\frac{\partial P}{\partial \rho} \right)_s \quad (29)$$

where the subscript s denotes the condition of constant entropy. The total differential of pressure dP can be found from equation (9).

$$dP = \sum_i dP_i \quad (30)$$

and the total differential of density $d\rho$ can be found from equation (10).

$$d\rho = \frac{M_r}{RT} dA - \frac{AM_r}{RT^2} dT \quad (31)$$

Then

$$\frac{dP}{d\rho} = \frac{\sum_i dP_i}{\frac{M_r}{RT} dA - \frac{AM_r}{RT^2} dT} = \frac{\sum_i p_i \frac{d \log p_i}{d \log T}}{\frac{AM_r}{RT} \left(\frac{d \log A}{d \log T} - 1 \right)}$$

Therefore

$$u^* = \left(\frac{\partial P}{\partial \rho} \right)_s = \frac{RT \sum_i p_i D_i}{AM_r (D_A - 1)} \quad (32)$$

where

$$D_t = \left(\frac{\partial \log n_i}{\partial \log T} \right)_s$$

$$D_A = \left(\frac{\partial \log A}{\partial \log T} \right)_s$$

This expression will permit evaluation of u^2 , provided the values of the partial derivatives D_t and D_A are found for conditions of chemical equilibrium and for an isentropic process. If the value of T is in degrees Kelvin and p_i in atmospheres the value of 8.3144×10^7 for R will give u in centimeters per second. The conditions of chemical equilibrium and constant entropy are introduced by writing the total differentials of equations (6) to (8) and (27). The total differential of these equations expressed in logarithmic variables and divided by $d \log T$ can be written, for gaseous products,

$$\frac{d \log p_i}{d \log T} - a_i \frac{d \log p_z}{d \log T} - b_i \frac{d \log p_y}{d \log T} - \dots - q_i = \frac{d \delta_i}{d \log T} \quad (33)$$

for liquid and solid products,

$$-a_i \frac{d \log p_z}{d \log T} - b_i \frac{d \log p_y}{d \log T} - \dots - q_i = \frac{d \delta_i}{d \log T} \quad (34)$$

and for all products of reaction,

$$\begin{aligned} \sum_i a_i n_i \frac{d \log n_i}{d \log T} - Aa \frac{d \log A}{d \log T} &= Aa \frac{d \log a}{d \log T} \\ \sum_i b_i n_i \frac{d \log n_i}{d \log T} - Ab \frac{d \log A}{d \log T} &= Ab \frac{d \log b}{d \log T} \\ \dots - \dots &= \dots \end{aligned} \quad (35)$$

$$\sum_i s_i \frac{d \log n_i}{d \log T} - As \frac{d \log A}{d \log T} + C' = As \frac{d \log s}{d \log T} \quad (36)$$

If $d \log s$ is taken as 0, s is a constant; if $d \log a$, $d \log b$, \dots , and $d \delta_i$ are taken as 0, mass is constant, atomic types are conserved, and rate of change in composition corresponds to constant values of δ_i . With these assumptions the partial derivatives D_t and D_A may be substituted for the total derivatives in equations (33) to (36). The augmented matrix formed from these equations may be partitioned in a manner similar to the combustion matrix. The resulting submatrices are shown in figure 4 with the sign reversed. When D_t and D_A are determined by means of the matrices shown in figure 4, the velocity of sound can be calculated from equation (32). This equation can be applied to mixtures of liquid and solid products in equilibrium as long as their volume is negligible compared with the volume of the gas mixture and provided the liquid and solid particles move in velocity and temperature equilibrium with the gas.

Specific heat.—The molar specific heat at constant pressure of a mixture in equilibrium may be found from equation (12) as follows:

$$C_p = \frac{A}{n} \left(\frac{\partial h}{\partial T} \right)_P = \frac{1}{nT} \left[\sum_i (H_P^o)_i n_i \left(\frac{\partial \log n_i}{\partial \log T} \right)_P - Ah \left(\frac{\partial \log A}{\partial \log T} \right)_P + TC' \right] \quad (37)$$

	$-D_1$	$-D_2$	.....	$-D_x$	$-D_Y$	.....	$-D_N$	$-D_s$
a	$a_1 n_1$	$a_2 n_2$	.....	0	0	0	0	$a_{NN} n_N$
b	$b_1 n_1$	$b_2 n_2$	.....	0	0	0	0	$b_{NN} n_N$
.....	.....	.....	.....	0	0	0	0	0
N	0	0	0	a_N	b_N	.....	0	0
s	s_1'	s_2'	.....	s_N'	s_Y'	.....	0	$s_N' - A_s$
								C'

(a) Submatrix $\left[\begin{array}{ c c } \hline \alpha_2 & \alpha_3 \\ \hline \end{array} \right]$.																																																																													
<table border="1"> <thead> <tr> <th></th><th>α_1</th><th>α_2</th><th>.....</th><th>1</th><th>0</th><th>0</th><th>0</th><th>0</th><th>0</th><th>0</th></tr> </thead> <tbody> <tr> <td>a</td><td>a_1</td><td>a_2</td><td>.....</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr> <tr> <td>b</td><td>b_1</td><td>b_2</td><td>.....</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr> <tr> <td>.....</td><td>.....</td><td>.....</td><td>.....</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr> <tr> <td>N</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td></tr> <tr> <td></td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td></tr> <tr> <td>q</td><td>q_1</td><td>q_2</td><td>.....</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td></tr> </tbody> </table>		α_1	α_2	1	0	0	0	0	0	0	a	a_1	a_2	0	1	0	0	0	0	0	b	b_1	b_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	N	0	0	0	0	0	0	0	1	0	0		0	0	0	0	0	0	0	0	1	0	q	q_1	q_2	0	0	0	0	0	0	1
	α_1	α_2	1	0	0	0	0	0	0																																																																			
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(b) Submatrix $\left[\begin{array}{ c } \hline -\alpha_i \\ \hline \end{array} \right] \text{ transposed.}$																																																																													
<table border="1"> <thead> <tr> <th></th><th>$-\alpha_1$</th><th>$-\alpha_2$</th><th>.....</th><th>$-\alpha_i$</th><th>$-\alpha_N$</th><th>$-\alpha_Y$</th><th>$-\alpha_s$</th><th>$-\alpha_N - A_s$</th><th>C'</th></tr> </thead> <tbody> <tr> <td>a</td><td>$-a_1$</td><td>$-a_2$</td><td>.....</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr> <tr> <td>b</td><td>$-b_1$</td><td>$-b_2$</td><td>.....</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr> <tr> <td>.....</td><td>.....</td><td>.....</td><td>.....</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr> <tr> <td>N</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td></tr> <tr> <td></td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td></tr> <tr> <td>q</td><td>$-q_1$</td><td>$-q_2$</td><td>.....</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td></tr> </tbody> </table>		$-\alpha_1$	$-\alpha_2$	$-\alpha_i$	$-\alpha_N$	$-\alpha_Y$	$-\alpha_s$	$-\alpha_N - A_s$	C'	a	$-a_1$	$-a_2$	0	0	0	0	0	0	0	b	$-b_1$	$-b_2$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	N	0	0	0	0	0	0	0	1	0	0		0	0	0	0	0	0	0	0	1	0	q	$-q_1$	$-q_2$	0	0	0	0	0	0	1	
	$-\alpha_1$	$-\alpha_2$	$-\alpha_i$	$-\alpha_N$	$-\alpha_Y$	$-\alpha_s$	$-\alpha_N - A_s$	C'																																																																				
a	$-a_1$	$-a_2$	0	0	0	0	0	0	0																																																																			
b	$-b_1$	$-b_2$	0	0	0	0	0	0	0																																																																			
.....	0	0	0	0	0	0	0																																																																			
N	0	0	0	0	0	0	0	1	0	0																																																																			
	0	0	0	0	0	0	0	0	1	0																																																																			
q	$-q_1$	$-q_2$	0	0	0	0	0	0	1																																																																			

FIGURE 4.—General form of submatrices of equations for partial derivatives at constant entropy.

where $n = \sum n_i$. Equation (30) can be written as

$$\sum_i p_i \frac{d \log n_i}{d \log T} = \frac{P d \log P}{d \log T} \quad (38)$$

If $d \log P$ is taken as 0, the pressure is constant; therefore, when equation (38) is substituted in the matrix of figure 4 in place of equation (36), the values of $\left(\frac{\partial \log n_i}{\partial \log T} \right)_P$ and $\left(\frac{\partial \log A}{\partial \log T} \right)_P$ can be found. These values can then be substituted in equation (37) to evaluate C_p^o .

Isentropic expansion to assigned Mach number.—According to the law of conservation of energy the sum of the enthalpy and the kinetic energy of a certain quantity of gas at any point in a nozzle is constant. If this sum per equivalent formula at any point l is denoted by a parameter h^* , then

$$h^* = \left[h + \frac{1}{2} M_l v^2 / J \right]_l \quad (39)$$

where v is the velocity of flow of the gas, J is a dimensional constant, and the subscript l indicates that the variables are evaluated at point l in the nozzle. The Mach number M of the flow is

$$M = \frac{v}{u} \quad (40)$$

Equations (32), (39), and (40) may be combined to give

$$h^* = \frac{\sum_i (H_P^o)_i n_i}{A} + \frac{M^2 R T \sum_i p_i D_t}{2 A (D_A - 1)} \quad (41)$$

where the value of R becomes 1.98718 (cal/(mole) ($^{\circ}$ K)). As the solution of the problem is found by successive adjustments of the estimated quantities, h^* approaches h_0 .

If equation (41) is expanded in a manner similar to that used to obtain equation (17) and if the differentials of derivatives are assumed to be negligible, the correction equation becomes

$$\sum_i h_i'' x_i - Ah^* x_A + T C'' x_T = \delta_{h^*} \quad (42)$$

where

$$h_i'' = h_i' + \frac{M^2 R T p_i D_i}{2(D_A - 1)}$$

$$\delta_{h^*} = Ah^* \log \frac{h_0}{h^*}$$

$$C'' = \sum_i \left[n_i (C_p)_i + \frac{M^2 R p_i D_i}{2(D_A - 1)} \right]$$

Equation (42), together with equations (13) to (15) and (28), constitute the correction equations for the isentropic expansion to an assigned Mach number. The coefficients of these equations form the submatrices shown in figure 5.

In order to carry out the numerical computations, values of n_i , A , and T are estimated for the assigned conditions; the values of D_i and D_A are obtained by means of the submatrices of figure 4, and used to compute the numerical values of the elements of the bottom row of figure 5(a). The submatrices of figure 5 are then used to compute the values of the corrections to n_i , A , and T . This process can be repeated until the assigned conditions are satisfied.

	x_1	x_2	---	x_N	x_A	x_T		
a	$a_1 n_1$	$a_2 n_2$	---	n_N	0	0	$a_{NN} N$	$-Aa$
b	$b_1 n_1$	$b_2 n_2$	---	0	n_Y	0	$b_{NN} N$	$-Ab$
---	---	---	---	0	0	---	---	0
N	0	0	0	---	---	0	0	0
S	0	0	0	a_N	b_N	0	0	q_N
h^*	a_1'	a_2'	---	s_x'	s_Y'	---	s_N'	$-As$
	b_1''	b_2''	---	h_x''	h_Y''	---	h_N''	$-Ah^*$
								TC''

(a) Submatrix $\begin{bmatrix} a_1 & a_2 \\ b_1 & b_2 \end{bmatrix}$.

	a_1	a_2	---	1	0	0	0	0	0
a	a_1	a_2	---	0	1	0	0	0	0
b	b_1	b_2	---	0	0	0	0	0	0
---	---	---	---	0	0	0	0	0	0
N	0	0	0	0	0	0	1	0	0
S	0	0	0	0	0	0	0	1	0
q	q_1	q_2	---	0	0	0	0	0	1
d	d_1	d_2	---	0	0	0	0	0	1

(b) Submatrix $\begin{bmatrix} -\alpha_1 \\ U_1 \end{bmatrix}$ transposed.

FIGURE 5.—General form of submatrices of correction equations for isentropic expansion to assigned Mach number.

Throat area of supersonic nozzle.—The process of isentropic expansion to a local Mach number of 1 is particularly interesting in the determination of the throat area of a nozzle having greater than critical pressure ratio. By assuming that the flow is isentropic and that chemical equilibrium is maintained throughout the expansion process, the flow velocity v at the throat must be equal to the velocity of sound u at the throat. The values n_i , A , T , and u can be found for a Mach number of 1 by use of the procedure given.

The throat area t can be calculated from the equation

$$\frac{t}{m} = \frac{RT}{AM_u} \quad (43)$$

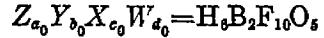
where m is the mass flow per second. If T is in degrees Kelvin and u is in centimeters per second, R equal to 82.0567 $(\text{cm}^3 \text{ (atm)}) / (\text{mole} \text{ } ^{\circ}\text{K})$ will give t/m in $(\text{cm}^2) (\text{sec}) / (\text{gm})$. This equation can be applied to mixtures of liquid or solid phases in equilibrium provided that the volume occupied by the liquid and the solid phases is negligible compared with that of the gas phase and that the particles of liquid and solid are in thermal and velocity equilibrium with the gas phase.

EXAMPLE OF COMBUSTION OF DIBORANE WITH OXYGEN BIFLUORIDE

The calculation of equilibrium temperature and composition of the reaction of 1 mole of diborane (B_2H_6) with 5 moles of oxygen bifluoride (OF_2) is illustrated in this example for processes of

- (a) constant-pressure adiabatic combustion
- (b) isentropic expansion to 1 atmosphere
- (c) isentropic expansion to the local velocity of sound

An equivalent formula of these reactants is



and $a_0=6$, $b_0=2$, $c_0=10$, and $d_0=5$.

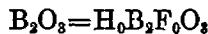
The following gaseous products will be considered as the products of reaction: boron trifluoride BF_3 , boron trioxide B_2O_3 , boron fluoride BF , boron hydride BH , boron oxide BO , diatomic boron B_2 , hydrogen H_2 , water vapor H_2O , hydroxyl radical OH , hydrogen fluoride HF , oxygen O_2 , fluorine F_2 , atomic hydrogen H , atomic boron B , atomic fluorine F , and atomic oxygen O . No liquids or solids are included. If the products are numbered in the order given, they can be identified in the terminology of equation (1) as follows:



and therefore

$$a_1=0, b_1=1, c_1=3, \text{ and } d_1=0$$

Similarly,



and

$$a_2=0, b_2=2, c_2=0, \text{ and } d_2=3$$

All values of a_i , b_i , c_i , and d_i for this problem, together with the thermodynamic properties used, are listed in table I. Although these thermodynamic values and the enthalpies of B_2H_6 and of OF_2 have since been revised, and therefore do not correspond to the values listed in the thermodynamic tables presented in a later section, they are adequate for the purpose of this example. The enthalpy values used are

$$(H_{298.16}^{\circ})_{\text{liquid B}_2\text{H}_6} = 570.149 \text{ kilocalories per mole}$$

$$(H_{298.16}^{\circ})_{\text{liquid OF}_2} = 67.077 \text{ kilocalories per mole}$$

The enthalpy of the amount of fuel and oxidant at initial conditions corresponding to the equivalent formula is, from equation (11),

$$h_o = 570.149 + 5(67.077) = 905.534 \frac{\text{kilocalories}}{\text{equivalent formula}} \quad (44)$$

The values of a_i , b_i , c_i , d_i , and h_o are constant for all parts of this example.

COMBUSTION PROCESS

The adiabatic combustion process was assumed to occur at a constant pressure of 20.4 atmospheres.

First estimate.—From previous computations or from simple calculations with equilibrium constants, estimating reasonable values for the composition and the temperature is usually possible. This procedure is recommended inasmuch as close estimates reduce the number of trials that must be made. In order to show that an arbitrary composition which is not based on probable final values of the composition

can be used, however, the first estimates for this example for n_i and A have been taken equal to 1 mole and a temperature of 4000° K. The possibility of divergence is discussed in a later section. All estimated quantities will be used with three decimal places to distinguish them from numbers that are always integers.

Evaluation of submatrices.—The numerical values of the elements of the submatrices shown in figures 2(a) and 2(b) can now be computed and are shown in figure 6. The steps are as follows:

1. The values of a_i , b_i , c_i and d_i are entered in rows a, b, c, and d of figure 6(b) and a 1 is entered on each square of the diagonal of $[U_k]$ according to figure 2(b).

2. Values of $q_i = \left(\frac{\Delta H}{RT}\right)_i$ from tables of thermodynamic functions are entered in row q of figure 6(b). In this case they are obtained from table I.

3. The values of the elements of the δ row of figure 6 (b) may be computed from equation (6) for gaseous products

$$\delta_i = \log p_i - a_i \log p_H - b_i \log p_B - c_i \log p_F - d_i \log p_O - \log K_i$$

The values of $\log K_i$ are obtained from tables of thermodynamic properties, in this case table I. Because all molecules and atoms are estimated to be 1, their logarithms are 0 so that in this case

$$\delta_i = -\log K_i$$

4. The estimated values of n_i are entered in row p of figure 6 (a). In case liquids or solids are present their value will be zero.

	Gaseous molecules												Atoms						
	x_{BF_3}	$x_{\text{B}_2\text{O}_3}$	x_{BF}	x_{BH}	x_{BO}	x_{B_2}	x_{H_2}	$x_{\text{H}_2\text{O}}$	x_{OH}	x_{HF}	x_{O_2}	x_{F_2}	x_{H}	x_{B}	x_{F}	x_{O}	x_{A}	x_{T}	Const

a	0	0	0	1.000	0	0	2.000	2.000	1.000	1.000	0	0	1.000	0	0	0	-8.000	0	-0.999
b	1.000	2.000	1.000	1.000	1.000	2.000	0	0	0	0	0	0	0	1.000	0	0	-9.000	0	-5.879
c	3.000	0	1.000	0	0	0	0	0	0	1.000	0	2.000	0	0	1.000	0	-8.000	0	0.775
d	0	3.000	0	0	1.000	0	0	1.000	1.000	0	2.000	0	0	0	0	1.000	-9.000	0	-2.297
p	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0	0	1.888
k	.721	2.334	2.629	3.569	2.527	5.720	.995	.577	.765	.820	.373	.960	1.051	3.177	.826	.794	-27.346	6.446	-13.125

(a) Submatrix $\begin{bmatrix} \alpha_1 & \alpha_2 \\ \vdots & \vdots \end{bmatrix}$.

a	0	0	0	1	0	0	2	2	1	1	0	0	1	0	0	0	0	0	0
b	1	2	1	1	1	2	0	0	0	0	0	0	0	1	0	0	0	0	0
c	3	0	1	0	0	0	0	0	0	1	0	2	0	0	1	0	0	0	0
d	0	3	0	0	1	0	0	1	1	0	2	0	0	0	0	1	0	0	0
p	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
q	-62.075	-80.693	-17.288	-8.300	-18.183	-7.959	-13.939	-29.209	-13.603	-19.574	-15.313	-8.705	0	0	0	0	1	0	0
k	-5.695	-5.109	-1.634	2.611	-1.083	2.763	0.406	0.347	0.167	-1.894	0.380	3.137	0	0	0	0	0	0	1

(b) Submatrix $\begin{bmatrix} -\alpha_1 \\ U_k \end{bmatrix}$ transposed.

FIGURE 6.—Numerical example of submatrices of correction equations for adiabatic combustion of diborane and oxygen bifluoride after first estimate of n_i , A , and T .

5. The values of the elements in rows **a**, **b**, **c**, and **d** of figure 6 (a), except columns x_A , x_T , and constant, are obtained by multiplying the value of n_i by the value of the corresponding element of the respective row in figure 6 (b). For example, the entries in the first column are $0 \times 1.000 = 0$, $1 \times 1.000 = 1.000$, $3 \times 1.000 = 3.000$ and $0 \times 1.000 = 0$.

6. Values of the elements of row **h** of figure 6 (a), except columns x_A , x_T , and constant, are obtained by multiplying the value of n_i by the value of (H_T^o) , from tables of thermodynamic functions, in this case table I. For example, the entry in the first column is $72,172 \times 1.000 = 72,172$. All values in row **h** have been divided by 10^6 .

7. The values of the elements of column x_A figure 6 (a) are obtained by summing elements to the left in each row and writing the negative of the total in column x_A except for row **p** where the value is zero.

8. The value of the x_T column (fig. 6 (a)) is zero except for the **h** row where the value is $T \sum (C_p^o) n_i$. The values of (C_p^o) are obtained from tables of thermodynamic functions, in this case table I.

9. Values of the constant column for figure 6 (a) for all rows except row **p** are found as follows: The value already entered in the x_A column for row **a** is $-Aa$. With the estimated value of $A=1.000$

$$a = \frac{Aa}{A} = \frac{8.000}{1.000} = 8.000$$

$$\delta_a = Aa \log \frac{a}{a}$$

$$= 8.000 \log \frac{6}{8.000} = -0.999$$

the values of δ_b , δ_c , δ_d , and δ_h are found in a similar manner.

x_H	x_B	x_F	x_O	x_A	x_T	Const
12.000	1.000	1.000	3.000	-8.000	-127.878	1.391
1.000	13.000	4.000	7.000	-9.000	-283.010	-16.322
1.000	4.000	16.000	0	-8.000	-240.597	-13.564
3.000	7.000	0	17.000	-9.000	-383.400	-17.383
8.000	9.000	8.000	9.000	0	-204.871	-3.866
8.854	28.736	7.861	12.414	-27.346	-454.757	-7.663

(a) Matrix $[\alpha_i]$ obtained from matrix multiplication $[\alpha_1; \alpha_2] \begin{bmatrix} -\alpha_1 \\ U_k \end{bmatrix}$.

x_H	0.08333	0.08333	0.2500	-0.6667	-10.656	0.1169
1.000	12.917	0.3032	0.5226	-0.6451	-21.085	-1.273
1.000	3.917	14.729	-0.1880	-0.3263	-10.004	-0.5902
3.000	6.750	-2.297	12.364	-0.2745	-14.727	-0.8487
8.000	8.333	4.807	3.395	18.210	-4.857	0.8731
8.854	27.998	-1.386	-4.644	-5.102	172.652	0.1544

(b) Matrix $[\alpha_i]$ (Crout's auxiliary matrix of $[\alpha_i]$).

x_H	x_B	x_F	x_O	x_A	x_T
1.299	0.8290	1.222	1.459	0.1232	0.1544

(c) Values of corrections (Crout's final matrix).

FIGURE 7. Numerical example of the solution of correction equations by matrix methods.

10. The constant column of row **p** is found as follows: The sum of the elements of row **p** is the pressure $P=16.000$; δ_p is computed from the formula

$$\delta_p = P \log \frac{P_o}{P}$$

$$\delta_p = 16.000 \log \frac{20.4}{16.000} = 1.688$$

The matrix multiplication $[\alpha_1; \alpha_2] \begin{bmatrix} -\alpha_1 \\ U_k \end{bmatrix}$ will result in the matrix $[\alpha_5]$ shown in figure 7 (a). The steps of this multiplication are shown in standard textbooks such as reference 7. Crout's auxiliary matrix corresponding to $[\alpha_5]$ may then be constructed and is shown in figure 7 (b) and the values of x_H , x_B , x_F , x_O , x_A , and x_T are shown in figure 7 (c). The values of the remaining functions are computed with the aid of equation (23). The solution is found to be

$$\begin{aligned} x_{BF_3} &= 0.7056 & x_{OH} &= 0.4907 \\ x_{B_2O_3} &= -1.100 & x_{HF} &= 1.377 \\ x_{BF} &= 1.116 & x_{O_2} &= 0.1737 \\ x_{BH} &= 1.665 & x_{F_2} &= -2.037 \\ x_{BO} &= 0.6135 & x_H &= 1.299 \\ x_{B_2} &= -2.139 & x_B &= 0.9290 \\ x_{H_2} &= 0.03982 & x_p &= 1.222 \\ x_{H_2O} &= -0.7999 & x_O &= 1.459 \\ x_A &= 0.1232 & x_T &= 0.1544 \end{aligned}$$

These values are to be applied to the initial estimates for n_i , A , and T according to the equation

$$(\log n_i)_{\text{second estimate}} = (\log n_i)_{\text{first estimate}} + x_i \quad (45)$$

For example, the second estimate of n_{BF_3} would be

$$(\log n_{BF_3})_{\text{second estimate}} = \log 1.000 + 0.7056$$

$$(n_{BF_3})_{\text{second estimate}} = 5.077$$

The second estimates of n_i , A , and T are then used to set up new submatrices according to the procedure described. The process is repeated until the desired accuracy has been obtained. For this example, six approximations were required to give the following final values of n_i , A , and T :

$$\begin{aligned} n_{BF_3} &= 2.6593 & n_{OH} &= 0.6785 \\ n_{B_2O_3} &= 0.1235 & n_{HF} &= 7.1456 \\ n_{BF} &= 0.1936 & n_{O_2} &= 0.9210 \\ n_{BH} &= 0.0001 & n_{F_2} &= 0.0003 \\ n_{BO} &= 0.1669 & n_H &= 1.7694 \\ n_{B_2} &= 0 & n_B &= 0.0577 \\ n_{H_2} &= 0.1271 & n_F &= 1.3043 \\ n_{H_2O} &= 0.0627 & n_O &= 5.1903 \\ A &= 1.6622 & T &= 4775.5^\circ K \end{aligned}$$

Discussion of convergence.—In order to demonstrate the convergence of the process with large errors in the first estimate, the example of the combustion of diborane and fluorine oxide was solved by using 1 mole of each product, a value of 1 for A , and a temperature of 4000°K for the first estimate. Because these first estimates were made without regard for the probable final values, large errors were present in the second approximation and six approximations were required to eliminate the error. The convergence is shown in terms of the parameters a, b, c, d, P, h , and ϵ in the following table where ϵ is defined as

$$\epsilon = \sum_i \left| \log k_i \right| + \left| \log \frac{a_i}{a} \right| + \left| \log \frac{b_i}{b} \right| + \left| \log \frac{c_i}{c} \right| + \left| \log \frac{d_i}{d} \right| + \left| \log \frac{P_i}{P} \right| + \left| \log \frac{h_i}{h} \right|$$

RESULTS OF APPROXIMATIONS								
Parameter	First estimate	Trial number						Desired value
		1	2	3	4	5	6	
a	8	96.840	7.005	6.286	6.079	6.002	6.000	6.000
b	9	23.346	11.605	2.653	2.325	2.008	2.000	2.000
c	5	51.540	24.082	13.104	10.541	10.016	10.000	10.000
d	9	29.641	11.951	33.660	5.240	5.022	5.000	5.000
P	16	125.485	38.000	52.494	21.416	20.436	20.400	20.400
h	2734.615	12,055.015	2090.090	2098.980	968.988	912.888	906.594	905.534
ϵ	26.892	5.861	4.092	2.805	.537	.011	.002	0

This method has been used in routine computation for several years without encountering a divergent case in a practical problem. At least for special cases when temperature is assigned, the process will converge for all values of the first estimates. Divergence is known to occur for certain cases where temperature is used as a variable when the first estimate of temperature and composition is sufficiently in error. Although no mathematical analysis has been made to determine the theoretical limits of convergence, the process appears to be satisfactory for practical computation.

Special treatment would be required if divergence is encountered. Obtaining convergence should be possible by a sufficiently close new estimate of composition and temperature. This procedure is recommended when it is feasible but other procedures can be devised, depending on the individual case.

ISENTROPIC EXPANSION TO FIXED PRESSURE

The temperature and the composition of the products of reaction following an isentropic-expansion ratio of 20.4 at chemical equilibrium were also computed for the products of reaction of this example. The value of s_0 is found from equation (26) by using the final values of each constituent of the adiabatic combustion and the absolute entropy values corresponding to the final combustion temperature. The calculated value of s_0 was 763.476 calories per $^\circ\text{K}$ per mole.

First estimates.—The number of approximations necessary

for a complete calculation can be considerably reduced if the initial estimate is based on previous experience. The final values of n_i and A determined for the combustion process of this example can therefore be the basis for this first estimate.

Because the expansion ratio is 20.4, the four largest components can be estimated to be $1/20.4$ of their combustion value.

$$\begin{aligned}n_{\text{BF}_3} &= 0.1304 \\n_{\text{HF}} &= 0.3503 \\n_{\text{H}} &= 0.0867 \\n_{\text{O}} &= 0.2544 \\A &= 0.0815\end{aligned}$$

For convenience of presentation, the temperature was estimated to be 4000°K so that the values of table I could be used again. The remaining products can be estimated from the dissociation equations by setting $\log k_i = 0$. For example, p_F would be determined with the assumed values of p_{HF} and p_{H} from equation (6) and table I ($p_i = n_i$)

$$\begin{aligned}0 &= \log 0.3503 - \log 0.0867 - \log p_F - 1.8944 \\&\log p_F = -0.45556 + 1.06198 - 1.8944 \\&= -1.28798 \\p_F &= 0.0515\end{aligned}$$

Similarly, p_B can be estimated with the assumed values of p_{BF_3} and p_{F}

$$\begin{aligned}0 &= \log 0.1304 - \log p_B - 3 \log 0.0515 - 5.6953 \\&\log p_B = -0.88472 + 3.86394 - 5.6953 \\p_B &= 0.0019\end{aligned}$$

If this procedure is followed for all the remaining constituents, the following list of first estimates can be made:

$$\begin{aligned}n_{\text{BF}_3} &= 0.1304 & n_{\text{OH}} &= 0.0150 \\n_{\text{B}_2\text{O}_3} &= 0.0078 & n_{\text{HF}} &= 0.3503 \\n_{\text{BF}} &= 0.0043 & n_{\text{O}_2} &= 0.0269 \\n_{\text{BH}} &= 0 & n_{\text{F}_2} &= 0 \\n_{\text{BO}} &= 0.0053 & n_{\text{H}} &= 0.0867 \\n_{\text{B}_2} &= 0 & n_{\text{B}} &= 0.0019 \\n_{\text{H}_2} &= 0.0029 & n_{\text{F}} &= 0.0515 \\n_{\text{H}_2\text{O}} &= 0.0009 & n_{\text{O}} &= 0.2544 \\A &= 0.0815 & T &= 4000^\circ\text{K}\end{aligned}$$

Construction of submatrices.—The construction of the submatrices may now be carried out and is shown in figure 8. The steps are the same as for the combustion example except for steps 6 to 9, which are different because the enthalpy equation has been replaced with the entropy equation.

The values of the elements of row s of figure 8(a) are obtained from the expression

$$s' = n_i [(S^o)_i - 1.98718 - 4.57565 \log p_i]$$

The values of $(S^o)_i$ are obtained from tables of thermodynamic data, in this case table I. For example, the entry in the first column is computed to be

$$\begin{aligned}(s_{\text{BF}_3})' &= 0.1304 (105.951 - 1.98718 - 4.57565 \log 0.1304) \\&= 14.0848\end{aligned}$$

7. The values of the entries in the x_A column of figure 8(a) are obtained in the same manner as for figure 6(a) except for the s row where the sum of the elements of the p row times 1.98718 is added to the sum of the elements of the s row and entered in column x_A .

8. The value of the entries in the x_T column is zero except for the s row where it is $\sum n_i(C_p)_i$. The values of $(C_p)_i$ are obtained from tables of thermodynamic data, in this case table I.

9. The value of δ_s is found in a manner similar to δ_e .

ISENTROPIC EXPANSION TO MACH NUMBER OF 1

The temperature and the composition of the products of reaction following an isentropic expansion to the local velocity of sound was computed for the products of reaction considered in this example, assuming chemical equilibrium. The value of s_e is the same as that found for the isentropic expansion to 1 atmosphere.

First estimate.—For simplicity, the same first estimates of 1 mole, 1, and 4000° K, for n_i , A , and T , respectively, were again made.

Construction of submatrices.—The submatrices corresponding to figure 5 may be constructed and are shown in figure 9.

The submatrices corresponding to figure 4 are first constructed. The steps are the same as for figure 8 except that row p and the constant column are omitted. The matrix

multiplication may then be carried out and the values of the partial derivatives D_i and D_A computed in a manner similar to the computation in the combustion example. These values of D_i and D_A together with $(H_T)_i$ are used to calculate the elements of row h^* of figure 9(a) except columns x_A , x_T , and constant. For example, when the values of $D_{BF_3} = 12.990$ and $D_A = 19.039$ are used, the value of

$$(h_{BF_3})'' = (h_{BF_3})' + \frac{M^2 R T p_{BF_3} D_{BF_3}}{2(D_A - 1)} \text{ becomes } 75,034 = 72,172 + \frac{1 \times 1.98718 \times 4000 \times 1.000 \times 12.990}{2(19.039 - 1)} \text{ (cal)}$$

All values in row h^* have been divided by 10^6 .

The value of the element in row h^* , column x_A is the sum of the elements to the left. The element in row h^* , column x_T is given by

$$TC'' = T \sum_i [n_i(C_p)_i + \frac{M^2 R p_i D_i}{2(D_A - 1)}]$$

and the value of the constant column is obtained as in the previous examples. Matrix multiplication that was carried out for the determination of D_i and D_A values may now be extended by an additional row and column and the value of x_t , x_A , and x_T found as in the previous examples. These values may then be used to obtain the second estimates for n_i , A , and T and the computation repeated until the desired accuracy has been obtained.

Gaseous molecules													Atoms						
	x_{BF_3}	$x_{B_2O_3}$	x_{BF}	x_{BH}	x_{BO}	x_{B_3}	x_{H_2}	x_{H_2O}	x_{OH}	x_{HF}	x_{O_2}	x_F_3	x_H	x_B	x_T	x_O	x_A	x_T	Const
a	0	0	0	0	0	0	0.0058	0.0018	0.0150	0.3503	0	0	0.0867	0	0	0	-0.4596	0	0.01238
b	0.1304	0.0156	0.0043	0	0.0053	0	0	0	0	0	0	0	0	0.0019	0	0	-1.1675	0	0.00235
c	0.3912	0	0.0043	0	0	0	0	0	0	0.3503	0	0	0	0	0.0515	0	-0.7973	0	0.00760
d	0	0.0234	0	0	0.0053	0	0	0.0009	0.0150	0	0.0533	0	0	0	0	0.2544	-0.3828	0	0.02208
p	0.1304	0.0078	0.0043	0	0.0053	0	0.0029	0.0009	0.0150	0.3503	0.0269	0	0.0867	0.0019	0.0515	0.2544	0	0	0.02505
s	14.0848	0.9704	0.3569	0	0.4137	0	0.1751	0.0760	1.0562	21.4213	2.0438	0	3.7435	0.1140	2.8395	13.2827	-62.4405	8.464	0.09447

(a) Submatrix $\left[\begin{array}{c|c} \alpha_2 & \alpha_3 \end{array} \right]$.

a	0	0	0	1	0	0	2	2	1	1	0	0	1	0	0	0	0	0	0
b	1	2	1	1	1	2	0	0	0	0	0	0	0	1	0	0	0	0	0
c	3	0	1	0	0	0	0	0	0	1	0	2	0	0	1	0	0	0	0
d	0	3	0	0	1	0	0	1	1	0	2	0	0	0	0	1	0	0	0
e	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
q	-62.075	-80.593	-17.288	-8.300	-18.183	-7.989	-13.939	-29.209	-13.603	-19.674	-15.813	-8.705	0	0	0	0	1	0	
s	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

(b) Submatrix $\left[\begin{array}{c} -\alpha_1 \\ U_h \end{array} \right]$ transposed.

FIGURE 8.—Numerical example of submatrices of correction equations for isentropic expansion to 1 atmosphere for the reaction of diborane with oxygen bifluoride after first estimate of n_i , A , and T .

	Gaseous molecules												Atoms						
	x_{BF_3}	$x_{B_2O_3}$	x_{BF}	x_{BH}	x_{BO}	x_{B_2}	x_{H_2}	x_{H_2O}	x_{OH}	x_{HF}	x_{O_2}	x_{F_2}	x_H	x_B	x_F	x_O	x_A	x_T	Const
a	0	0	0	1.000	0	0	2.000	2.000	1.000	1.000	0	0	1.000	0	0	0	-8.000	0	-0.993
b	1.000	2.000	1.000	1.000	1.000	2.000	0	0	0	0	0	0	0	1.000	0	0	-9.000	0	-5.879
c	3.000	0	1.000	0	0	0	0	0	0	1.000	0	2.000	0	0	1.000	0	-8.000	0	0.755
d	0	3.000	0	0	1.000	0	0	1.000	1.000	0	2.000	0	0	0	0	1.000	-9.000	0	-2.297
s	103.964	114.773	71.917	59.425	67.633	68.503	49.067	70.471	62.002	59.067	68.796	68.826	38.319	47.562	49.562	49.492	-103.944	161.162	-103.234
h*	0.750	2.364	2.672	3.623	2.569	5.778	1.035	0.624	0.513	0.347	0.427	1.026	1.056	3.215	0.889	0.839	-28.035	-7.113	-13.760

(a) Submatrix $\begin{bmatrix} \alpha_1 & \alpha_1 \end{bmatrix}$.

a	0	0	0	1	0	0	2	2	1	1	0	0	1	0	0	0	0	0
b	1	2	1	1	1	2	0	0	0	0	0	0	0	1	0	0	0	0
c	3	0	1	0	0	0	0	0	0	1	0	2	0	0	1	0	0	0
d	0	3	0	0	1	0	0	1	1	0	2	0	0	0	0	1	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
q	-62.075	-80.593	-17.288	-8.300	-18.183	-7.969	-13.939	-20.209	-13.803	-19.674	-15.313	-8.705	0	0	0	0	1	0
δ	-5.695	-5.109	-1.634	2.611	-1.033	2.768	0.406	0.347	0.167	-1.894	0.880	3.137	0	0	0	0	0	1

(b) Submatrix $\begin{bmatrix} -\alpha_1 \\ U_k \end{bmatrix}$ transposed.FIGURE 9.—Numerical example of submatrices of correction equations for isentropic expansion to local velocity of sound for reaction of diborane and oxygen bifluoride after first estimate of n_k , A and T.

TABLES OF THERMODYNAMIC PROPERTIES

Tables of thermodynamic data, completed June 1949, are presented for the following substances:

A	Al(g)	B	C	Cl	F	H	e^-	Li	N	O
	Al(s)	B_1	CO	Cl_2	F_2	H_2	F^-	LiF	N_2	O ₂
	Al(liq)	BF	CO ₂	ClF	HCl	Li ⁺	LiH	NO	NO	OH
	AlO	BF_3			HF					
	Al ₂ O ₃ (g)	BF ₃								
	Al ₂ O ₃ (s)	BO								
	Al ₂ O ₃ (liq)	B ₂ O ₃ (g)								
		B ₂ O ₃ (s)								
		B ₂ O ₃ (liq)								

These tables are taken from NACA TN 2161 except that the values for BF have been revised. Many of the data in the tables are based upon estimated vibrational frequencies or insufficient spectroscopic or thermochemical data to provide accurate data at high temperatures. Nevertheless, the data are considered sufficiently accurate for engineering evaluations of performance of aircraft propulsion systems until better data become available.

PREPARATION OF TABLES

The values of enthalpy and entropy below 1000° K and the values of specific heat at all temperatures were based upon data taken from the literature or calculated by NACA from spectroscopic data or estimated fundamental frequencies. The calculations were made by use of the accurate summation method described in reference 8 or by the use of the tables prepared by F. J. Krieger of Douglas Aircraft Company, Inc. based upon a harmonic oscillator. The

values of enthalpy and entropy above 1000° K were computed from the specific-heat data and these values were then used to compute the values of the remaining functions.

The thermodynamic functions computed by NACA are based upon the fundamental constants from reference 9 and are given in terms of the thermochemical calorie defined as 4.18400 absolute joules (reference 10).

Specific heat.—The specific-heat data were interpolated and extrapolated when necessary to obtain values of C_p^o at 298.16° K and every 100° from 300° to 6000° K. In many cases these C_p^o data were smoothed by the following method: Values of the first differences of C_p^o for 100° K intervals δC_p^o were plotted against temperature and a smooth curve drawn. New values of C_p^o were then computed from the values of δC_p^o read from the curve. In some cases the new C_p^o values were tabulated to more decimal places than the original data. Care was taken to see that the new C_p^o values were within about 1 or 2 units in the last tabulated place of the reference data in all but a few cases in which the reference data were irregular.

In order to minimize the labor required to integrate C_p^o to obtain the other functions, a linear variation of C_p^o was assumed by use of the equation

$$C_p^o = c_1 + c_2 T \quad (46)$$

where c_1 and c_2 are constants evaluated for each 100° temperature interval above 1000° K.

The maximum difference between a smooth function representing C_p^o and the series of 50 straight-line segments represented by equation (46) is usually less than 0.005 percent at any temperature. In a few cases near $1000^\circ K$ the error approaches 0.05 percent.

Enthalpy and entropy.—The data for enthalpy and entropy below $1000^\circ K$ were taken from the literature or computed at the Lewis laboratory and when necessary interpolated to give the values at $298.16^\circ K$ and every 100° from 300° to $1000^\circ K$.

The values above $1000^\circ K$ were obtained by integration of equation (46) for C_p^o , using the constants for each $100^\circ K$ temperature interval.

The value of the change of enthalpy δH_r^o for a temperature change $\delta T = T - T_1$ is given by

$$\delta H_r^o = \int_{T_1}^T C_p^o dT = \bar{C}_p^o \delta T \quad (47)$$

where \bar{C}_p^o is given by

$$\bar{C}_p^o = (C_p^o)_1 + \frac{c_2}{2} \delta T \quad (48)$$

and $(C_p^o)_1$ is the value of C_p^o corresponding to the temperature T_1 . The corresponding change in entropy δS_r^o is given by

$$\delta S_r^o = \int_{T_1}^T \frac{C_p^o}{T} dT = c_1 \delta \ln T + c_2 \delta T \quad (49)$$

where $\delta \ln T$ is given by

$$\delta \ln T = \ln T - \ln T_1 \quad (50)$$

Values of enthalpy and entropy for each 100° above $1000^\circ K$ were obtained by accumulatively adding to the values at $1000^\circ K$ the changes of enthalpy and entropy computed for each 100° interval by means of equations (47) and (49).

The values of enthalpy and entropy were computed to more decimal places than are tabulated and then rounded. Equations (47) and (49) may therefore occasionally yield values that differ by one unit in the last tabulated place of enthalpy and entropy because of rounding. Inconsistencies from this source are unavoidable and are not considered in the following discussion.

The representation of C_p^o from 1000° to $6000^\circ K$ by means of 50 straight-line segments permitted computation of self-consistent values of enthalpy and entropy but lead to values slightly different from those that would have resulted from a more laborious integration of a smooth C_p^o function. For example, the values of enthalpy at $6000^\circ K$ differ from those obtained by applying Simpson's one-third rule by 0.0045, 0.0012, 0.0038, and 0.0031 percent for H_2O , H_2 , CO_2 , and BF_3 , respectively.

In a few cases, discrepancies exist between the reference values of enthalpy and the values of enthalpy given herein that cannot be accounted for by the error resulting from the method of integration used. From an analysis of the values in the reference tables, these discrepancies appear to be caused by a combination of small inconsistencies and round-

ing errors in the references. The maximum discrepancy noted in enthalpy occurred in H_2O and was less than 0.25 percent of the value of $H_r^o - H_0^o$.

Enthalpy H_r^o .—For convenience of computation, tables of enthalpy H_r^o , the sum of the sensible enthalpy $H_r^o - H_0^o$ and chemical energy at $0^\circ K$ H_0^o , were prepared. An arbitrary base may be adopted for assigning absolute values to the enthalpy of various substances inasmuch as only differences in enthalpy are measurable. The base used in these tables was selected to obtain positive values for H_r^o of the substances commonly used as rocket and ram-jet propellants and occurring in the products of combustion; it is shown in the following table:

Base substance	Phase	Temperature ($^\circ K$)	Enthalpy assigned, H_r^o (kcal/mole)
A	Gas	0	0
AlF ₃	Crystal	298.16	0
BF ₃	Gas	0	0
CO ₂	Gas	0	0
Cl ₂	Gas	298.16	10
HF	Gas	0	0
H ₂ O	Crystal	0	0
LiF	Gas	298.16	80
N ₂	Crystal	0	0
O ₂	Crystal	0	0
e ⁻	Gas	0	00

In determining the value of H_r^o to be assigned to a substance having a known heat of formation, it is convenient to use the values of H_r^o assigned to the elements as shown in the following table:

Element	Phase	Enthalpy assigned, H_r^o (kcal/mole)	
		0° K	298.16° K
A	Gas	0	1.4812
Al	Crystal	293.6251	234.0951
B	Crystal	173.3793	173.3793
C	Graphite	91.9274	92.1700
Cl ₂	Gas	7.8061	10.0000
F ₂	Gas	60.9562	63.0699
H ₂	Gas	67.4169	66.4407
I ₂	Crystal	132.2250	132.2250
N ₂	Gas	1.6992	3.7718
O ₂	Gas	2.0362	4.1109
e ⁻	Gas	60.0000	61.4812

For example, if the value of enthalpy H_r^o to be assigned to H_2O (liq) is to be determined at $298.16^\circ K$, the reaction of formation would be



and ΔH_f^o is defined as

$$\Delta H_f^o = (H_r^o)_{H_2O} - (H_r^o)_{H_2} - \frac{1}{2}(H_r^o)_{O_2} \quad (52)$$

therefore,

$$(H_r^o)_{H_2O} = \Delta H_f^o + (H_r^o)_{H_2} + \frac{1}{2}(H_r^o)_{O_2} \quad (53)$$

With the use of the value $\Delta H_f^o = -68.3174$ (kcal/mole),

$$(H_r^o)_{H_2O} = -68.3174 + 69.4407 + \frac{1}{2}(4110.9)$$

$$= 3178.75 \text{ (cal/mole)}$$

For convenience, the values of H_r° thus assigned to a number of compounds have been computed with the aid of data from references 8 and 10 to 23 and are listed in table II. The energy of gas imperfections has been included in computing the values of H_r° assigned to the liquid phase of ammonia, *n*-butane, chlorine, hydrogen, and water.

$-\Delta H^{\circ}/RT$ and $\ln K$.—From the values of H_r° and S_r° obtained as previously described, the values of $-\Delta H^{\circ}/RT$ and $\ln K$ were computed for the reaction of formation of each substance from its elements in the atomic gas state. For example, the reaction of formation of H_2O is



From the definitions of ΔH° and $\ln K$

$$\frac{\Delta H^{\circ}}{RT} = \frac{(H_r^{\circ})_{H_2O} - 2(H_r^{\circ})_H - (H_r^{\circ})_O}{RT} \quad (55)$$

and

$$\ln K = \frac{(S_r^{\circ})_{H_2O} - 2(S_r^{\circ})_H - (S_r^{\circ})_O}{R} - \frac{(H_r^{\circ})_{H_2O} - 2(H_r^{\circ})_H - (H_r^{\circ})_O}{RT} \quad (56)$$

As shown by equations (3) and (4), K may be expressed in terms of partial pressures. For example, for gaseous H_2O ,

$$K = \frac{p_{H_2O}}{p_H^2 p_O}$$

The values of $\ln K$ have been converted to $\log K$ in the tables for convenience.

INTERPOLATION OF TABLES

Interpolation formulas are given that permit computation of self-consistent values of the thermodynamic functions at temperatures intermediate to those tabulated. Linear interpolation is recommended for simplicity, however, when a high degree of self-consistency is not required. Interpolation formulas such as those of Newton or Lagrange will give values near the self-consistent value. Inasmuch as the tables are based on linear variations in C_p° , linear interpolation yields self-consistent results for the C_p° function. An example of the values obtained by the interpolation formulas given and by linear interpolation is shown for each function.

Interpolation of specific heat.—The value of C_p° for any temperature T is given by

$$C_p^{\circ} = (C_p^{\circ})_1 + \frac{\delta T}{T_2 - T_1} [(C_p^{\circ})_2 - (C_p^{\circ})_1] \quad (57)$$

where $(C_p^{\circ})_1$ and $(C_p^{\circ})_2$ are the tabular values corresponding to the tabular temperatures T_1 and T_2 between which T lies and $\delta T = T - T_1$. For example, the value of C_p° for H_2O at 1573.4° K is computed to be

$$C_p^{\circ} = 11.134 + \frac{73.4}{100} (11.343 - 11.134) \\ = 11.287 \text{ (cal/(mole) }(^{\circ}\text{K}))$$

Interpolation of enthalpy.—The value of H_r° for any temperature T is given by

$$H_r^{\circ} = (H_r^{\circ})_1 + \bar{C}_p^{\circ} \delta T \quad (58)$$

where $(H_r^{\circ})_1$ is the value listed at T_1 and where

$$\bar{C}_p^{\circ} = \frac{(C_p^{\circ})_1 + C_p^{\circ}}{2}$$

For example, for H_2O at 1573.4° K

$$\bar{C}_p^{\circ} = \frac{11.134 + 11.287}{2} = 11.211 \text{ (cal/(mole) }(^{\circ}\text{K}))$$

$$H_r^{\circ} = 25,202.3 + 11.211 \times 73.4 = 26,025.2 \text{ (cal/mole)}$$

By linear interpolation,

$$H_r^{\circ} = 26,027.2 \text{ (cal/mole)}$$

Interpolation of entropy.—Self-consistent values of entropy may be obtained with the aid of equation (49), which may be approximated by

$$\delta S_r^{\circ} = \bar{C}_p^{\circ} \delta \ln T \quad (60)$$

from which S_r° may be written

$$S_r^{\circ} = (S_r^{\circ})_1 + \bar{C}_p^{\circ} \delta \ln T \quad (61)$$

where $(S_r^{\circ})_1$ is the value listed at T_1 .

Equation (61) yields self-consistent values to within 0.0001 (cal/(mole) $(^{\circ}\text{K})$) for all substances tabulated at temperatures above 1600° K and for all substances except Al_2O_3 (s and g), BF_3 , B_2O_3 (liq and g), CO_2 , and H_2O for temperatures from 1000° to 1600° K. For these substances, the error due to use of equation (61) does not exceed 0.0003 cal/(mole) $(^{\circ}\text{K})$, but equation (49) may be used if greater self-consistency is desired.

For example, for H_2O at 1573.4° K,

$$S_r^{\circ} = 59.8687 + 11.211 (\ln 1573.4 - \ln 1500) \\ = 60.4043 \text{ (cal/(mole) }(^{\circ}\text{K}))$$

By linear interpolation,

$$S_r^{\circ} = 60.4010 \text{ (cal/(mole) }(^{\circ}\text{K}))$$

Interpolation of $-\Delta H^{\circ}/RT$ and $\log K$.—The values of $-\Delta H^{\circ}/RT$ and $\log K$ for any temperature T are given by

$$\frac{-\Delta H^{\circ}}{RT} = \left(\frac{-\Delta H^{\circ}}{RT} \right)_1 - \frac{\delta T}{100} \left(\frac{a}{T} + b \right) \quad (62)$$

and

$$\log K = (\log K)_1 - \frac{\delta T}{100} \left(\frac{c}{T} + d \right) \quad (63)$$

where $(-\Delta H^{\circ}/RT)_1$ and $(\log K)_1$ are the values corresponding to T_1 and where a , b , c , and d are interpolation coefficients corresponding to T_1 .

For example, for H_2O at 1573.4° K,

$$\frac{-\Delta H^{\circ}}{RT} = 76.3615 - \frac{73.4}{100} \left(\frac{73.66}{1573.4} + 0.05315 \right) = 72.8862$$

By linear interpolation,

$$\frac{-\Delta H^{\circ}}{RT} = 72.9433$$

and for $\log K$,

$$\log K = 20.5727 - \frac{73.4}{100} \left(\frac{3276}{1573.4} + 0.02690 \right) = 19.0247$$

By linear interpolation,

$$\log K = 19.0501$$

SOURCES OF DATA

A summary of the heat of formation and spectroscopic constants used in computing the tables and the references from which these data were taken are given in table III together with a summary of the source and the treatment of specific-heat, enthalpy, and entropy data. Additional discussion for a few substances follows.

$\text{Al}_2\text{O}_3(\text{s}, \text{liq}, \text{g})$.—The properties of Al_2O_3 in the solid, liquid, and gaseous phases were approximated by starting with data at 298.16°K for the solid phase and computing the properties of each phase from specific-heat data and enthalpy changes associated with phase changes. The specific heat for the solid was computed from a formula for C_p° given in reference 27. The value of $S_{298.16}^{\circ}$ for the solid was taken from selected values of National Bureau of Standards (issued undated but prior to June 30, 1948). The values of enthalpy and entropy up to 1000°K were then found by integration of the C_p° formula given in reference 27. The heat of fusion ($\Delta H_{\text{fusion}}^{\circ}=6000 \text{ cal/mole}$ at 2320°K) was taken from reference 25. The C_p° values for $\text{Al}_2\text{O}_3(\text{liq})$ above 2320°K were calculated from a formula based upon data given in reference 25.

Inasmuch as data on gaseous Al_2O_3 are unavailable in the literature, it was assumed that C_p° values for $\text{Al}_2\text{O}_3(\text{g})$ are the same as those for $\text{B}_2\text{O}_3(\text{g})$ given in reference 29. The heat of vaporization ($\Delta H_{\text{vaporation}}^{\circ}=115.7 \text{ kcal/mole}$ at boiling point of $2980 \pm 60^\circ\text{C}$) was taken from reference 40. The uncertainty in the values given for entropy and enthalpy is estimated to be ± 10 percent.

BF_3 .—Since publication of Technical Note 2161, new thermodynamic data have been computed for BF_3 based upon a ${}^1\sum$ ground state and a dissociation energy of 4.3 electron volts as quoted by reference 30.

BF_3 .—The thermodynamic functions of BF_3 were computed by the rigid-rotator-harmonic-oscillator approximation with the following spectroscopic data given in references 31 and 41:

	Vibrational frequencies		Moment of inertia (g) (cm ²)
	B^{11}F_3 (cm ⁻¹)	B^{10}F_3 (cm ⁻¹)	
ν_1	888	888	$I_1=157.7 \times 10^{-40}$
ν_2	691.3	719.5	$I_2=78.84 \times 10^{-40}$
$\nu_3(2)$	1445.9	1497	$I_3=78.84 \times 10^{-40}$
$\nu_4(2)$	480.4	482.0	
Relative abundance (percent)	81.17	18.83	

$\text{B}_2\text{O}_3(\text{g})$.—The value for the heat required to convert solid B_2O_3 at 0°K to gaseous B_2O_3 at 1500°K listed in reference 29 as 106.065 (kcal/mole) was used to compute the value of $(H_{1500}^{\circ})_{\text{B}_2\text{O}_3(\text{g})}$. The values of $(S_{1500}^{\circ})_{\text{B}_2\text{O}_3(\text{g})}$ and $(H_{1500}^{\circ}-H_0^{\circ})_{\text{B}_2\text{O}_3(\text{g})}$ were taken from reference 29. The remaining values of enthalpy and entropy were computed by integration of the specific-heat data.

Cl_2 and HCl .—The C_p° data for Cl_2 and HCl from 1000° to 6000°K were taken from unpublished data obtained at the Jet Propulsion Laboratory of the California Institute of Technology.

ClF , F , and F^- .—Recent spectroscopic and thermochemical measurements on compounds of fluorine (reference 42)

have indicated that the values of the heat of formation of ClF , F , and F^- are considerably less than the values given in reference 18. In a communication in May 1949, Dr. F. D. Rossini of the National Bureau of Standards listed their best current estimate for the heat of formation of ClF and F as -13.2 and 17.8 (kcal/mole), respectively. In accordance with these new values, the value of the heat of formation of F^- has been recalculated from data in reference 18.

HF .—The values of C_p° , H_T° , $-H_0^{\circ}$, and S_T° for HF at 298.16°K 600°K , and every 1000° from 1000° to 6000°K were computed from spectroscopic data given in reference 36 using the accurate summation process. Intermediate values of C_p° were interpolated. Subsequent to the completion of computations for this substance, new spectroscopic data were made available by Dr. A. H. Nielsen of the University of Tennessee. Values of C_p° , H_T° , $-H_0^{\circ}$, and S_T° at 5000°K computed with these data differ from values herein by 1 percent for C_p° , 0.2 percent for $H_T^{\circ}-H_0^{\circ}$, and 0.03 percent for S_T° .

e^- , F^- , and Li^+ .—The use of metals with low ionization potentials introduces the possibility of the formation of appreciable quantities of ionized products. Because the partial pressure of ions is expected to be small, the zero-pressure properties of electron gas e^- have been tabulated from reference 38. The properties of F^- have been computed on the assumption that only the ground electronic state is stable. (See reference 43, p. 218.) The contributions of all energy levels above the ground level to the thermodynamic functions of Li^+ are negligible. The value of C_p° tabulated for all these substances is $\frac{5}{2} R$.

Li .—In computing the thermodynamic functions of Li , the summation was carried over the first five energy levels.

LiF .—Spectroscopic data for LiF gas were not found in the literature. A vibrational frequency for the ground state of 1343 (cm⁻¹) and a moment of inertia $I_0=15.415 \times 10^{-40}$ (gm) (cm²) were graphically estimated from a plot of force constants against difference in atomic number of the two elements composing the substances NaH , C_2 , and BeO , each substance of which is isoelectronic with LiF . It is expected that the anharmonicity constant for LiF is sufficiently large to increase materially the computed value of the specific heat. The uncertainty in the value of the enthalpy and the entropy is estimated to be ± 10 percent at 5000°K .

LiH .—Spectroscopic data for Li^+H^1 given in reference 26 were modified for the normal isotopic mixture LiH using relative abundance percentages of isotopes and atomic weights given in reference 44 (pp. 163 and 188, respectively). The value obtained for the vibrational frequency of the ground state of LiH is 1360.37 (cm⁻¹) and for the moment of inertia is 3.77246×10^{-40} (gm) (cm²).

$\text{H}_2\text{O}(\text{s})$, $\text{N}_2(\text{s})$, and $\text{O}_2(\text{s})$.—The heat required to heat solid H_2O , N_2 , and O_2 from 0° to 298.16°K in the natural state was taken from reference 37.

New data.—Subsequent to the completion of the computation for H_2 , new values for C_p° , internal energy $E^{\circ}-E_0^{\circ}$, and S_T° were published in reference 45 and differ from the values in this report at 5000°K by 0.5 percent for C_p° , 0.1 percent for $H_T^{\circ}-H_0^{\circ}$, and 0.02 percent for S_T° .

TABLES OF THERMODYNAMIC PROPERTIES

The values of the functions of the 42 substances are given in tables IV to XLV at 298.16° K and every 100° from 300° to 6000° K together with interpolation coefficients for $-\Delta H^\circ/RT$ and $\log K$ at every 100° from 1000° to 6000° K.

LEWIS FLIGHT PROPULSION LABORATORY,
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
CLEVELAND, OHIO, January 26, 1950.

APPENDIX—SYMBOLS

The following symbols are used in this report:

A	number of formula weights of reactants	n	number of moles
a, b, \dots	summation of each atomic type over products of reaction per equivalent formula; with subscript, number of atoms of each element within chemical formula; in thermodynamic tables, interpolation coefficients	P	total pressure
C°	molar specific heat at constant pressure and standard conditions (cal/(mole) (°K))	p	partial pressure
C', C''	specific heat coefficient for matrix	Q	any function
C°	molar specific heat at constant volume and standard conditions	q, r	any variables; with subscript, matrix symbol for $\frac{\Delta H}{RT}$
D	operator $(\frac{\partial \log}{\partial \log T})$	R	universal gas constant, 1.98718 (cal/(mole) (°K))
E_r°	molar internal energy at standard conditions	S_r°	molar entropy at standard conditions (cal/(mole) (°K))
e	internal energy per equivalent formula	s	entropy per equivalent formula; in thermodynamic tables, solid phase of substance
F_r°	molar free energy at standard conditions	s'	entropy coefficient for matrix
g	gas phase of substance	T	temperature (°K)
H_0°	chemical energy at 0° K and standard conditions (kcal/mole)	t	throat area
H_r°	sum of sensible enthalpy and chemical energy at temperature T and standard conditions (kcal/mole)	U_m, U_k	unit matrix
$H_r^\circ - H_0^\circ$	sensible enthalpy at temperature T and standard conditions (kcal/mole)	u	velocity of sound
$\frac{\Delta H^\circ}{RT}$	enthalpy change due to formation of substance from its elements in atomic gas state divided by RT	V	volume
ΔH_r°	enthalpy change due to formation of substance from its elements in standard state (kcal/mole)	r	velocity of flow
h	enthalpy per equivalent formula	Z, Y, \dots	elements within representative chemical formula
h', h''	enthalpy coefficient for matrix	x	correction variables
h^*	sum of heat and kinetic energies per equivalent formula	$\alpha_1, \alpha_2, \dots$	submatrices
hc/k	ratio of Planck's constant times velocity of light to Boltzmann's constant, 1.43847 (cm) (°K)	Δ	increment
I	moment of inertia (gm) (cm ²)	δ	increment due to a temperature change; with subscript, error parameter
J	dimensional constant	ϵ	total-error parameter
K	equilibrium constant	$v_1, v_2, v_3(2)$	spectroscopic constants
liq	liquid phase of substance	$v_4(2)$	
M	Mach number	$\omega_s, \omega_e \omega_e$	spectroscopic constants
M_r	molecular weight of equivalent formula	ρ	density
m	mass flow per second	Subscripts:	
N	number of products of reaction	a, b, \dots	number of atoms within chemical formula
		f	fuel
		g	oxidant
		l	any point in nozzle
		m	number of types of gaseous molecule
		o	initial given condition
		P	constant pressure
		s	constant entropy
		T	temperature (°K)
		$\dots Y, Z$	product index numbers (i) that designate atomic gases
		$i, \dots N$	product index number

REFERENCES

- Brinkley, Stuart R., Jr.: Calculation of the Equilibrium Composition of Systems of Many Constituents. *Jour. Chem. Phys.*, vol. 15, no. 2, Feb. 1947, pp. 107-110.
- Krieger, F. J., and White, W. B.: A Simplified Method for Computing the Equilibrium Composition of Gaseous Systems. *Jour. Chem. Phys.*, vol. 16, no. 4, April 1948, pp. 358-360.
- Huff, Vearl N., and Calvert, Clyde S.: Charts for the Computation of Equilibrium Composition of Chemical Reactions in the Carbon-Hydrogen-Oxygen-Nitrogen System at Temperatures from 2000° to 5000° K. *NACA TN 1653*, 1948.
- Winternitz, Paul F.: A Method for Calculating Simultaneous, Homogeneous Gas Equilibria and Flame Temperatures. Third Symposium on Combustion and Flame and Explosion Phenomena. The Williams & Wilkins Co. (Baltimore), 1949, pp. 628-633.

5. Scarborough, James B.: Numerical Mathematical Analysis. Johns Hopkins Press (Baltimore), 1930, pp. 187-190.
6. Crout, Prescott D.: A Short Method for Evaluating Determinants and Solving Systems of Linear Equations with Real or Complex Coefficients. AIEE Trans. (Suppl.), vol. 60, 1941, pp. 1235-1241.
7. Pipes, Louis A.: Applied Mathematics for Engineers and Physicists. McGraw-Hill Book Co., Inc. (New York and London), 1946, pp. 78-79.
8. Woolley, Harold W.: Thermodynamic Functions for Molecular Oxygen in the Ideal Gas State. Nat. Bur. Standards Jour. Res., vol. 40, no. 2, Feb. 1948, pp. 163-168.
9. DuMond, Jesse W. M., and Cohen, E. Richard: Our Knowledge of the Atomic Constants F, N, m, and h in 1947, and of Other Constants Derivable Therefrom. Rev. Modern Phys., vol. 20, no. 1, Jan. 1948, pp. 82-108.
10. Anon.: Tables of Selected Values of Chemical Thermodynamic Properties. Nat. Bur. Standards, Dec. 31, 1947.
11. Anon.: Tables of Selected Values of Chemical Thermodynamic Properties. Nat. Bur. Standards, June 30, 1948.
12. Rossini, Frederick D., Pitzer, Kenneth S., Taylor, William J., Ebert, Joan P., Kilpatrick, John E., Beckett, Charles W., Williams, Mary G., and Werner, Helene G.: Selected Values of Properties of Hydrocarbons. Circular C461, Nat. Bur. Standards, Nov. 1947.
13. Woolley, Harold W.: Dry Air (Ideal Gas State). Table 2.10 of the NBS-NACA Tables of Thermal Properties of Gases. Nat. Bur. Standards, July 1949.
14. Anon.: Handbook of Chemistry and Physics, Charles D. Hodgman, ed. Chem. Rubber Pub. Co. (Cleveland), 29th ed., 1945.
15. Hulme, R. E.: Thermodynamic Properties of Superheated Chlorine. Chem. Eng., vol. 56, no. 11, Nov. 1949, pp. 118-119, 127.
16. Anon.: Tables of Selected Values of Chemical Thermodynamic Properties. Nat. Bur. Standards, Sept. 30, 1949.
17. Beckett, C. W., Clarke, J. T., and Johnston, H. L.: Tentative Thermal Functions for Diborane. Joint Rep. 7 on Proj. 319 and Rep. 4 on Proj. 309, Ohio State Univ. Res. Foundation, Aug. 1, 1948. (USAF Contract W33-038-ac-17721 and ONR Contract N6onr-225, T. O. IX, NR 058 061).
18. Anon.: Tables of Selected Values of Chemical Thermodynamic Properties. Nat. Bur. Standards, June 30, 1947.
19. Woolley, Harold W., Scott, Russell B., and Brickwedde, F. G.: Compilation of Thermal Properties of Hydrogen in Its Various Isotopic and Ortho-Para Modifications. Nat. Bur. Standards Jour. Res., vol. 41, no. 5, Nov. 1948, pp. 379-475.
20. Kelley, K. K.: Contributions to the Data on Theoretical Metallurgy. III. The Free Energies of Vaporization and Vapor Pressures of Inorganic Substances. Bull. 383, Bur. Mines, 1935.
21. Kelley, K. K.: Contributions to the Data on Theoretical Metallurgy. V. Heats of Fusion of Inorganic Substances. Bull. 393, Bur. Mines, 1936.
22. Davis, William D., Mason, Leo S., and Stegeman, Gebhard: Thermal Properties of Some Hydrides. Tech. Rep., Dept. Chem., Univ. Pittsburgh, Dec. 1, 1948. (Contract No. N60RI-48, T. O. No. 1.)
23. Anon.: Tables of Selected Values of Chemical Thermodynamic Properties. Nat. Bur. Standards, March 31, 1948.
24. Bacher, Robert F., and Goudsmit, Samuel: Atomic Energy States. McGraw-Hill Book Co., Inc., 1932.
25. Terebesi, L.: Die Thermodynamischen Funktionen von Aluminium. α -Aluminiumoxyd, β -Graphit, Sauerstoff und Kohlenmonoxyd. Helvetica Chim. Acta, vol. 17, fasc. IV, 1934, pp. 804-819.
26. Herzberg, Gerhard: Molecular Spectra and Molecular Structure. Vol. I. Prentice-Hall, Inc., 1939.
27. Shomate, C. Howard, and Naylor, B. F.: High-Temperature Heat Contents of Aluminum Oxide, Aluminum Sulfate, Potassium Sulfate, Ammonium Sulfate and Ammonium Bisulfate. Jour. Am. Chem. Soc., vol. 67, no. 1, Jan. 1945, pp. 72-75.
28. Anon.: Tables of Selected Values of Chemical Thermodynamic Properties. Nat. Bur. Standards, Sept. 30, 1948.
29. Wacker, Paul F., Woolley, Harold W., and Fair, Myron F.: Thermodynamic Properties and Gaseous Equilibria of Boron, Oxygen and the Oxides of Boron. Tech. Rep. to Bur. Aero., Navy Dept. submitted by Heat and Power Div., Nat. Bur. Standards, Jan. 25, 1945.
30. Herzberg, Gerhard: Molecular Spectra and Molecular Structure. Vol. I. D. Van Nostrand Company, Inc., 1950.
31. Spencer, Hugh M.: Thermodynamic Properties of Gaseous Boron Trifluoride, Boron Trichloride, and Boron Tribromide. Jour. Chem. Phys., vol. 14, no. 12, Dec. 1946, pp. 729-732.
32. Anon.: Tables of Selected Values of Chemical Thermodynamic Properties. Nat. Bur. Standards, March 31, 1947.
33. Anon.: Tables of Selected Values of Chemical Thermodynamic Properties. Nat. Bur. Standards, June 30, 1949.
34. Ward, J. J., and Hussey, M. A.: Estimated Thermodynamic Functions of Free Radicals in Combustion Gases. Third Symposium on Combustion and Flame and Explosion Phenomena, The Williams & Wilkins Co. (Baltimore), 1949, pp. 599-610.
35. Moore, Charlotte E.: Atomic Energy Levels, vol. 1, sec. 1. Circular 467, Nat. Bur. Standards, April 15, 1948.
36. Murphy, George M., and Vance, John E.: Thermodynamic Properties of Hydrogen Fluoride and Fluorine from Spectroscopic Data. Jour. Chem. Phys., vol. 7, no. 9, Sept. 1939, pp. 806-810.
37. Anon.: International Critical Tables. Vol. 5. McGraw-Hill Book Co., Inc., 1929, p. 176.
38. Gordon, A. R.: The Free Energy of Electron Gas. Jour. Chem. Phys., vol. 4, no. 10, Oct. 10, 1936, pp. 678-679.
39. Mulliken, Robert S.: The Low Electronic States of Simple Heteropolar Diatomic Molecules. Phys. Rev., vol. 50, no. 11, 2d ser., Dec. 1, 1936, pp. 1028-1040.
40. Ruff, Otto, und Konschak, Martin: Arbeiten im Gebiet hoher Temperaturen. Zeitschr. f. Elektrochem., Bd. 32, Nr. 11, Nov. 1926, S. 515-525.
41. Herzberg, Gerhard: Infrared and Raman Spectra of Polyatomic Molecules. D. Van Nostrand Co., Inc., 1945, p. 299.
42. Schmitz, Heinz, und Schumacher, Joachim: Das Bandenspektrum und die Dissoziationsenergie des ClF. Zeitschr. f. Naturforschung, Bd. 2a, Heft 6, Juni 1947, S. 359-363.
43. Herzberg, Gerhard: Atomic Spectra and Atomic Structure. Prentice-Hall, Inc., 1937. (Reprinted, Dover Pub. (New York), 1944, p. 218.)
44. Stranathan, J. D.: The "Particles" of Modern Physics. The Blakiston Co. (Philadelphia), 1942.
45. Johnston, H. L., Savedoff, L. G., and Beizer, J.: The Thermodynamic Properties of Hydrogen Gas from near Zero Degrees to 6000° K. Tech. Rep. No. 2, Proj. RF-316, Ohio State Univ. Res. Foundation, May 1, 1949. (ONR Proj. No. NR 058 005, Navy Contract No. N6onr-225, T. O. XII.)

TABLE I—VALUES OF CONSTANTS FOR REACTION OF DIBORANE WITH OXYGEN BIFLUORIDE ($B_2H_6 + 5F_2O$)

Product	Fixed					Determined at estimated temperature of 4000° K				
	i	b _i	a _i	c _i	d _i	(H_f°) _i kcal/mole	($\Delta H_f^{\circ}/RT$) _i	(S_f°) _i	(C_p°) _i	log K _i
Equivalent formula	0	2	6	10	5					
BF_3	1	1	0	3	0	72.172	-62.0753	105.951	19.738	5.6953
B_2O_3	2	2	0	0	3	233.435	-60.5932	116.760	25.660	5.1094
BF	3	1	0	1	0	262.961	-17.2834	73.904	8.905	1.8342
BH	4	1	1	0	0	358.994	-8.3004	61.412	8.826	-2.6110
BO	5	1	0	0	1	262.739	-18.1834	69.620	9.065	1.0327
B_2	6	2	0	0	0	572.083	-7.9892	70.580	8.926	-2.7625
H_2	7	0	2	0	0	99.593	-13.9385	51.054	9.151	-0.4061
H_2O	8	0	2	0	1	57.706	-29.2092	72.458	13.300	-0.3470
OH	9	0	1	0	1	76.560	-13.8031	63.989	9.185	-0.1663
HF	10	0	1	1	0	32.016	-19.6738	61.054	9.045	1.8944
O_2	11	0	0	0	2	37.310	-15.8125	70.783	9.932	-0.3804
F_2	12	0	0	2	0	96.012	-8.7047	70.813	9.451	-3.1373
H	13	0	1	0	0	105.192	-----	40.306	4.968	-----
B	14	1	0	0	0	317.778	-----	49.549	4.968	-----
F	15	0	0	1	0	82.601	-----	51.230	4.974	-----
O	16	0	0	0	1	79.493	-----	51.479	5.091	-----

TABLE II—ENTHALPY H_f° ASSIGNED TO SEVERAL SUBSTANCES

Substance	Formula	Phase	Temperature (°K)	Heat of formation, ΔH_f° (kcal/mole)	Enthalpy assigned, H_f° (kcal/mole)	Reference
Acetylene	C_2H_2	Gas	298.16	54.194	307.993	11
Air b		Liquid *	191.7	-----	302.75	12
Aluminum	Al	Gas	298.16	0	3.8208	13
Ammonia	NH_3	Crystal	298.16	0	224.6951	10
Aniline	$C_6H_5NH_2$	Liquid	298.76	-11.04	95.01	-----
n-Butane	C_4H_{10}	Gas	298.16	-----	68.91	10, 14
Chlorine	Cl ₂	Liquid	298.16	48.18	806.19	14
Chlorine trifluoride	ClF_3	Liquid	298.16	-29.812	686.108	12
Diborane	B_2H_6	Gas	272.66	-----	680.128	12, 14
Ethylene-diamine	$C_2H_2N_2$	Liquid	298.16	0	10.000	-----
Fluorine	F ₂	Gas	298.16	-----	6.5	15
Fluorine oxide	F ₂ O	Liquid	298.16	0	67.5	-----
Gasoline t	AN-F-58	Liquid	298.16	-32.1	662.6	16
Heptane	C_7H_{16}	Liquid	298.16	7.5	557.8	16, 17
Hexane	C_6H_{14}	Liquid	190.63	-----	459.53	11
Hydrazine	N_2H_4	Liquid	298.16	-5.36	62.0699	-----
Hydrazine hydrate	$N_2H_4 \cdot H_2O$	Liquid	298.16	0	60.04	18
Hydrogen	H ₂	Gas	298.16	-----	70.6	18
Hydrogen peroxide	H ₂ O ₂	Liquid	20.89	68.4	68.4	18
Hydroxylamine	NH ₂ OH	Liquid	298.16	-47.50	1346.60	19
Lithium	Li	Crystal	298.16	-58.83	1147.15	12
Lithium borohydride	LiBH ₄	Liquid	298.16	-47.62	901.84	12
Methane	CH ₄	Gas	298.16	12.05	154.70	10
Methanol	CH ₃ OH	Liquid	111.67	-57.93	156.20	10
Nitric acid, white fuming	HNO ₃	Liquid	298.16	0	69.4407	-----
Nitrogen tetraoxide	N ₂ O ₄	Gas	298.16	-----	67.546	19
Nitrogen trifluoride	NF ₃	Gas	298.16	-44.84	28.71	18
Nitromethane	CH ₃ NO ₂	Gas	298.16	-25.5	82.6	10
n-Octane	C_8H_{18}	Gas	298.16	0	132.2250	-----
Oxygen	O ₂	Gas	298.16	-----	134.53	20, 21
Ozone	O ₃	Liquid	90.16	-44.15	400.34	22
Pentaborane	B ₅ H ₉	Liquid	162.65	-17.889	213.171	12
Tetranitromethane	C(NO ₂) ₄	Liquid	298.16	0	209.71	12
Water	H ₂ O	Liquid	298.16	-57.036	176.050	23

* For pressure of 900 mm Hg.

b For composition consisting of following mole fractions: N₂, 0.780881; O₂, 0.209485; Al, 0.003324; CO₂, 0.000300.

e Energy of gas imperfections included.

d Computed from heat of combustion.

e Estimate based upon unpublished value of -26.4 kcal/mole at 200° C obtained by Dr. Swinehart of Harshaw Chemical Company.

f Based upon representative sample having molecular weight of 122 and hydrogen-carbon atom ratio of 1.942.

TABLE III—THERMOCHEMICAL AND SPECTROSCOPIC DATA AND REFERENCES FOR EACH SUBSTANCE

Substance	Phase	Heat of formation, ΔH_f° , (kcal/mole)		Spectroscopic constants		Reference			
		0° K	298.16° K	$\alpha_1 - 2\alpha_2 x_s$ (cm ⁻¹)	Moment of inertia (gm)(cm ²) $\times 10^{-4}$	Heat of formation	Spectroscopic constants	Specific heat, enthalpy, and entropy (0° to 1000° K)	Specific heat (1000° to 6000° K)
A	Gas.	0	0				24	(a)	(a)
Al	Gas.	67.50					24	(a)	(a)
Al	Crystal	0	0				25	25	44 25
Al	Liquid								
AlF ₃	Crystal	-320.8							
AlO	Gas.	37.8	963	43.8223		(b)	26	(a)	(a)
Al ₂ O ₃	Gas.								
Al ₂ O ₃	Crystal, α	-369.09						27	27
Al ₂ O ₃	Liquid							25	25
B	Gas.	97.2				28	29	(a)	(a)
B ₂	Crystal	0	0						
B ₂	Gas.	124				28	30	29	44 29
BF ₃	Gas.	-16.9208	1304.84	19.0466		b 30	30	(a)	(a)
BF ₃	Gas.	-265.2				28	31	(a)	(a)
BH ₃	Gas.	73.8	2288	2.36929		28	26	(a)	(a)
BO	Gas.	-5.2				28		29	eds 29
B ₂ O ₃	Gas.								eds 29
B ₂ O ₃	Crystal	-302.0					29		
B ₂ O ₃	Liquid								
C	Gas.	171.698				28		29	eds 11
C	Graphite	0	0					11	
CO	Gas.	-26.4157					32		
CO ₂	Gas.	-94.0518					32		
Cl	Gas.	28.61				33		11	
CH	Gas.	0						11	(a)
CF	Gas.	-13.2	778	54.35		(f)	34	(a)	(a)
F	Gas.	17.8				(f)	35	(a)	(a)
F ₂	Gas.	0	856	33.8564			36	(a)	(a)
H	Gas.	51.620				18		32	32
H ₂	Gas.	0	0					32	eds 19
HCl	Gas.	-22.063					11	11	(a)
HF	Gas.	-64.2				18	36	(a)	(a)
H ₂ O	Gas.	-57.7974				18		11	eds 11
H ₂ O	Crystal	-69.4350				b 37			
H ₂ O	Liquid	-68.3174				18			
C ₂	Gas.	0	0						
F ₂	Gas.	-78.5						38	38
Li	Gas.	161.4684				b 18	(f)	(a)	(a)
Li	Gas.	-38.150				b 24	24	(a)	(a)
Li	Crystal	0	0			b 20	24	(a)	(a)
LiF	Gas.	-83.766	1343	15.415		120	(f)	(a)	
LiH	Gas.	25.4564	1560.37	3.77240		b 139	26	(a)	(a)
N	Gas.	83.120				10		32	eds 11
N ₂	Gas.	0	0					32	eds 11
N ₂	Crystal	-1.6992				b 37			
NO	Gas.	21.477				10		18	eds 11
O	Gas.	58.586				32		32	eds 11
O ₂	Gas.	0	0					8	eds 8
O ₂	Crystal	-2.0362				b 37			
OH	Gas.	10.0				18		32	eds 11

* Specific heat, enthalpy, and entropy at 298.16° and every 100° from 300° to 1000° and specific heat for each 100° from 1000° to 6000° K were computed from spectroscopic data given in reference listed by accurate summation method.

^a Data from selected values of National Bureau of Standards issued undated but prior to June 30, 1948.

^b Graphically smoothed.

^c Extrapolated.

* Specific heat, enthalpy, and entropy at 298.16° and every 100° from 300° to 1000° and specific heat for each 100° from 1000° to 6000° K were computed from spectroscopic data by rigid rotator-harmonic oscillator approximation.

^f See discussion in text.

ⁱ Interpolated.

^o Computed with aid of data in reference listed.

¹ Unpublished data from Battelle Memorial Institute also used.

TABLE VI.—THERMODYNAMIC PROPERTIES OF AI (CRYSTAL)

[Atomic weight, 26.97]

T (°K)	C_p^o ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$H_F^o - H_0^o$ ($\frac{\text{kcal}}{\text{mole}}$)	H_F^o ($\frac{\text{kcal}}{\text{mole}}$)	S_F^o ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{\Delta H^o}{RT}$	$\log K$
0 298.16	5.80	0 1.0700	233.6261 234.6961	6.641	113.9245	42.3388
300	5.81	1.0820	234.7071	6.682	113.2214	42.0354
400	6.24	1.6860	235.3111	8.819	84.7945	29.7284
500	6.46	2.3210	235.9451	9.844	67.7029	22.3985
600	6.66	2.9760	236.6011	11.013	56.2898	17.4927
700	6.88	3.6530	237.2781	12.070	48.1210	14.0077
800	7.15	4.3530	237.9781	13.018	41.9794	11.4020
900	7.65	5.0890	238.7141	13.864	37.1822	9.3752
930	7.90	5.3240	238.9491	14.130	35.9345	8.8566

TABLE VII—THERMODYNAMIC PROPERTIES OF AI (LIQUID)

[Atomic weight, 26.97]

T (°K)	C_p^o ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$H_F^o - H_0^o$ ($\frac{\text{kcal}}{\text{mole}}$)	H_F^o ($\frac{\text{kcal}}{\text{mole}}$)	S_F^o ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$\frac{\Delta H^o}{RT}$	$\delta\left(-\frac{\Delta H^o}{RT}\right) = \frac{-\delta T}{100}\left(\frac{c}{T} + b\right)$		$\log K$	$\delta \log K = \frac{-\delta T}{100}\left(\frac{c}{T} + d\right)$	
						a	b		c	d
930	6.75	7.8240	241.4491	16.818	34.5838			8.8568		
1000	6.84	8.2900	241.9241	17.310	32.0993	-3271	0.03246	7.8061	1414	-0.01995
1100	6.968	8.9893	242.6144	17.9078	29.0932	2974	0.03217	6.5106	1285	-0.01953
1200	7.002	9.6822	243.3173	18.5794	24.0827	2726	.03228	5.4863	1178	-0.01955
1300	7.218	10.4077	244.0328	19.1520	24.4686	2617	.03174	4.6027	1087	-0.01923
1400	7.344	11.1358	244.7609	19.6916	22.6239	2337	.03190	3.8455	1009	-0.01887
1500	7.470	11.8765	245.5016	20.2025	21.0340	2181	.03198	3.1917	941	-0.01832
1600	7.596	12.6298	246.2549	20.6886	19.6389	2045	0.03186	2.6219	882	-0.01812
1700	7.722	13.3937	247.0208	21.1529	18.4041	1925	.03165	2.1212	830	-0.01811
1800	7.848	14.1742	247.7933	21.5978	17.3080	1818	.03186	1.6782	784	-0.01803
1900	7.974	14.9653	248.5904	22.0256	16.8145	1723	.03190	1.2836	742	-0.01780
2000	8.100	15.7690	249.3941	22.4377	15.4210	1636	.03175	.9302	705	-0.01751
2100	8.226	16.5953	250.2104	22.8360	14.6108	1558	0.03192	0.6120	671	-0.01740
2200	8.352	17.4142	251.0393	23.2216	13.8707	1487	.03188	.3244	640	-0.01706
2300	8.478	18.1857	251.8808	23.5966	13.1923	1423	.03168	.0632	612	-0.01700
2400	8.604	19.1098	252.7549	23.9591	12.5677	1363	.03190	-.1748	586	-0.01670
2500	8.730	19.9765	253.6616	24.3129	11.9906	1309	.03174	-.3925	562	-0.01655
2600	8.856	20.8538	254.4809	24.6577	11.4554	1259	0.03160	-.5921	540	-0.01630
2700	8.982	21.7477	255.3728	24.9943	10.9575	1212	.03184	-.7768	520	-0.01631
2800	9.108	22.6522	256.2773	25.3233	10.4980	1169	.03170	-.9452	501	-0.01618
2900	9.234	23.5933	257.1044	25.6451	10.0582	1129	.03147	-.1.1018	483	-0.01600
3000	9.360	24.4990	258.1241	26.9602	9.6504	-----	-----	-.1.2468	-----	-----

TABLE VIII—THERMODYNAMIC PROPERTIES OF AlO (GAS)

[Molecular weight, 42.97]

T (°K)	C_p (cal mole °K)	$H_f^o - H_0^o$ (kcal mole)	H_f^o (kcal mole)	S_f^o (cal mole °K)	$\frac{\Delta H^o}{RT}$	$\delta \left(\frac{-\Delta H^o}{RT} \right) = \frac{-\delta T}{100} \left(\frac{a}{T} + b \right)$	$\log K$	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c}{T} + d \right)$	
								c	d
0	—	0	272.4501	52.1648	149.9685	—	59.5342	—	—
298.16	7.3749	2.1005	274.5506	52.2101	148.0580	—	59.1848	—	—
300	7.3820	2.1140	274.5641	52.2101	148.0580	—	42.9281	—	—
400	7.7510	2.8711	275.8212	54.8856	112.1309	—	32.1770	—	—
500	8.0424	3.6615	276.1116	56.1482	89.9293	—	—	—	—
600	8.2630	4.4769	276.9270	57.6342	75.1020	—	26.6609	—	—
700	8.4038	5.3101	277.7602	58.9183	64.4956	—	21.9971	—	—
800	8.5122	6.1682	278.6063	60.0479	56.5311	—	18.4930	—	—
900	8.5924	7.0116	279.4617	61.0553	50.3305	—	15.7629	—	—
1000	8.6529	7.8740	280.8241	61.9639	45.3658	4456	0.01879	13.8755	0.01513
1100	8.6998	8.7416	281.1917	62.7008	41.3011	4054	0.01097	11.7831	1770
1200	8.7386	9.6134	282.0636	63.5493	37.9118	3719	0.00683	10.2874	1682
1300	8.7645	10.4884	282.9385	64.2496	35.0425	3435	0.00693	9.0200	1508
1400	8.7878	11.3660	283.8161	64.9000	32.5820	3191	0.00597	7.9323	1402
1500	8.8089	12.2457	284.6958	65.5070	30.4487	2980	0.00470	6.9884	1309
1600	8.8227	13.1272	285.5773	66.0789	28.5815	2795	0.00388	6.1614	1228
1700	8.8369	14.0101	286.4602	66.6111	26.9335	2632	0.00308	5.4808	1157
1800	8.8471	14.8943	287.3444	67.1165	25.4882	2387	0.00245	4.7805	1094
1900	8.8586	15.7795	288.2296	67.5951	24.1588	2357	0.00190	4.1980	1037
2000	8.8647	16.6655	289.1156	68.0496	22.9784	2240	0.00163	3.6732	986
2100	8.8718	17.5524	290.0025	68.4822	21.9881	2134	0.00130	3.1977	940
2200	8.8779	18.4399	290.8900	68.8951	20.9368	2037	0.00115	2.7650	898
2300	8.8833	19.3279	291.7780	69.2899	20.0500	1949	0.00102	2.3864	859
2400	8.8880	20.2155	292.6666	69.6830	19.2369	1869	0.00050	2.0064	824
2500	8.8922	21.1035	293.5558	70.0309	18.4858	1795	0.0022	1.6720	791
2600	8.8960	21.9949	294.4450	70.3798	17.7982	1727	-0.00013	1.3630	761
2700	8.8983	22.8847	295.3348	70.7156	17.1587	1663	-0.00023	1.0766	734
2800	8.9022	23.7747	296.2248	71.0893	16.5650	1605	-0.00065	.8108	708
2900	8.9060	24.6651	297.1162	71.3517	16.0122	1550	-0.00087	.5921	684
3000	8.9074	25.5557	298.0058	71.6593	15.4954	1500	-0.00127	.3302	662
3100	8.9096	26.4466	298.8967	71.9458	15.0128	1452	-0.00145	0.1129	640
3200	8.9116	27.3376	299.7877	72.2267	14.5615	1407	-0.00156	0.0909	621
3300	8.9134	28.2289	300.6790	72.5029	14.1367	1385	-0.00177	0.2827	602
3400	8.9150	29.1203	301.5704	72.7890	13.7370	1326	-0.00216	.4934	584
3500	8.9166	30.0119	302.4620	73.0275	13.3608	1269	-0.00238	.6389	568
3600	8.9180	30.9036	303.3537	73.2737	13.0048	1264	-0.00252	-0.7952	552
3700	8.9193	31.7955	304.2456	73.5230	12.6632	1221	-0.00262	-0.9479	533
3800	8.9205	32.6875	305.1376	73.7609	12.3497	1190	-0.00313	-1.0928	524
3900	8.9216	33.5796	306.0297	73.9627	12.0477	1160	-0.00320	-1.2304	511
4000	8.9226	34.4718	306.9219	74.2186	11.7609	1132	-0.00350	-1.3613	498
4100	8.9235	35.3641	307.8142	74.4389	11.4983	1106	-0.00393	-1.4859	486
4200	8.9244	36.2565	308.7066	74.6539	11.2289	1061	-0.00420	-1.6048	475
4300	8.9252	37.1490	309.5991	74.8639	10.9617	1057	-0.00443	-1.7183	464
4400	8.9260	38.0415	310.4916	75.0691	10.7459	1034	-0.00468	-1.8267	454
4500	8.9267	38.9342	311.3843	75.2697	10.5208	1012	-0.00490	-1.9305	444
4600	8.9274	39.8269	312.2770	75.4859	10.3057	991	-0.00515	-2.0299	434
4700	8.9280	40.7196	313.1697	75.6579	10.1000	972	-0.00560	-2.1262	425
4800	8.9286	41.6125	314.0626	75.8459	9.9031	953	-0.00579	-2.2186	416
4900	8.9291	42.5054	314.9656	76.0300	9.7144	935	-0.00610	-2.3045	407
5000	8.9296	43.3983	315.8584	76.2104	9.5335	918	-0.00650	-2.3839	400
5100	8.9301	44.2913	316.7414	76.3873	9.3800	901	-0.00667	-2.4702	391
5200	8.9306	45.1843	317.6344	76.5607	9.1934	886	-0.00707	-2.5484	384
5300	8.9310	46.0774	318.5275	76.7308	9.0328	871	-0.00740	-2.6238	377
5400	8.9314	46.9705	319.4206	76.8977	8.8794	857	-0.00782	-2.6965	369
5500	8.9318	47.8687	320.3138	77.0616	8.7314	843	-0.00814	-2.7666	363
5600	8.9322	48.7669	321.2070	77.2228	8.5890	830	-0.00851	-2.8344	356
5700	8.9326	49.6501	322.1002	77.3807	8.4519	817	-0.00876	-2.8999	349
5800	8.9329	50.5424	322.9935	77.5380	8.3198	805	-0.00904	-2.9632	343
5900	8.9332	51.4367	323.8868	77.6837	8.1924	793	-0.00942	-3.0245	337
6000	8.9335	52.3300	324.7801	77.8389	8.0697	—	-3.0839	—	—

TABLE IX—THERMODYNAMIC PROPERTIES OF Al_2O_3 (CRYSTAL, α)

[Molecular weight, 101.94]

T (°K)	C_p^o (cal mole °K)	$H_f^o - H_{1000}^o$ (kcal mole)	H_T^o (kcal mole)	S_T^o (cal mole °K)	$-\frac{\Delta H_f^o}{RT}$	$\delta - \left(\frac{\Delta H_f^o}{RT} \right) = -\frac{\delta T}{100} \left(\frac{a}{T} + b \right)$	log K	$\delta \log K = -\frac{\delta T}{100} \left(\frac{c}{T} + d \right)$	
								a	b
0									
200									
300									
400									
500									
600									
700									
800									
900									
1000	23.380	0	237.0838	91.5490	286.1479	28.430	0.10445	95.1916	13.409
1100	23.754	2.3557	239.4395	98.7929	280.1980	25.870	0.08207	83.8927	11.287
1200	24.064	4.7456	241.8304	95.9741	238.5576	28.735	.06471	74.4750	10.361
1300	24.311	7.1654	244.2492	97.8100	220.2352	21.925	.06289	66.5049	9.558
1400	24.510	9.6054	246.6602	99.6189	204.5218	20.373	.04260	59.6726	8.878
1500	24.672	12.0655	249.1493	101.3154	190.8973	19.026	.03603	53.7610	8.268
1600	24.805	14.5394	251.6232	102.9120	178.9710	17.846	0.02935	48.5698	7.771
1700	24.916	17.0254	254.1092	104.4191	168.4440	16.805	.02429	43.9972	7.315
1800	25.010	19.5217	256.6055	105.8459	159.0386	15.878	.02056	39.9331	6.910
1900	25.090	22.0267	259.1106	107.2008	150.7062	15.048	.01760	36.2068	6.547
2000	25.169	24.5392	261.6230	108.4890	143.1846	14.300	.01538	33.0243	6.220
2100	25.221	27.0582	264.1420	109.7180	136.3397	13.623	0.01353	30.0637	5.924
2200	25.277	29.5831	266.6869	110.8925	130.1339	13.008	.01155	27.3723	5.656
2300	25.329	32.1134	269.1972	112.0173	124.4696	12.447	.00965	24.9152	5.410
2400	25.374	34.6485	271.7323	113.0932	119.2707	11.933	.00780	22.6630	5.185
2500	25.408	37.1876	274.2714	114.1327	114.4597	11.460	.00601	20.5611	4.977

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TABLE XII—THERMODYNAMIC PROPERTIES OF B (GAS)

[Atomic weight, 10.82]

<i>T</i> (°K)	<i>C_p</i> (cal mole °K)	<i>H_T - H₀</i> (kcal mole)	<i>H_T</i> (kcal mole)	<i>S_T</i> (cal mole °K)
0		0	269.0896	
298.16	4.9704	1.5097	270.5793	36.0493
300	4.9704	1.5188	270.5884	36.0798
400	4.9693	2.0168	271.0884	38.1096
500	4.9688	2.5127	271.5823	39.2183
600	4.9686	3.0036	272.0792	40.1243
700	4.9684	3.5084	272.5700	40.8902
800	4.9683	4.0088	273.0729	41.5536
900	4.9682	4.5001	273.5697	42.1388
1000	4.9682	4.9959	274.0665	42.6625
1100	4.9682	5.4937	274.5633	43.1390
1200	4.9681	5.9905	275.0601	43.5683
1300	4.9681	6.4974	275.5570	43.9059
1400	4.9681	6.9942	276.0538	44.3341
1500	4.9681	7.4810	276.5506	44.6769
1600	4.9681	7.9778	277.0474	44.9975
1700	4.9681	8.4746	277.5442	45.2987
1800	4.9680	8.9714	278.0410	45.5827.
1900	4.9680	9.4682	278.5378	45.8013
2000	4.9680	9.9650	279.0349	46.1061
2100	4.9680	10.4618	279.5314	46.3485
2200	4.9680	10.9586	280.0282	46.5796
2300	4.9680	11.4554	280.5250	46.8004
2400	4.9680	11.9522	281.0218	47.0119
2500	4.9680	12.4490	281.5186	47.2147
2600	4.9680	12.9458	282.0154	47.4098
2700	4.9680	13.4426	282.5122	47.5970
2800	4.9680	13.9394	283.0000	47.7777
2900	4.9680	14.4362	283.5068	47.9520
3000	4.9680	14.9330	284.0026	48.1204
3100	4.9680	15.4298	284.4994	48.2833
3200	4.9680	15.9266	284.9962	48.4410
3300	4.9680	16.4234	285.4930	48.5939
3400	4.9680	16.9202	285.9898	48.7422
3500	4.9680	17.4170	286.4866	48.8862
3600	4.9680	17.9138	286.9834	49.0262
3700	4.9680	18.4106	287.4802	49.1628
3800	4.9680	18.9074	287.9770	49.2948
3900	4.9680	19.4042	288.4738	49.4238
4000	4.9681	19.9010	288.9706	49.5496
4100	4.9681	20.3978	289.4674	49.6723
4200	4.9681	20.8946	289.9642	49.7920
4300	4.9682	21.3914	290.4610	49.9089
4400	4.9682	21.8882	290.9579	50.0231
4500	4.9683	22.3851	291.4547	50.1348
4600	4.9685	22.8819	291.9515	50.2440
4700	4.9686	23.3788	292.4484	50.3509
4800	4.9688	23.8756	292.9452	50.4555
4900	4.9690	24.3725	293.4421	50.5579
5000	4.9692	24.8694	293.9390	50.6583
5100	4.9694	25.3664	294.4360	50.7567
5200	4.9697	25.8633	294.9329	50.8532
5300	4.9701	26.3603	295.4299	50.9479
5400	4.9705	26.8574	295.9270	51.0408
5500	4.9710	27.3544	296.4240	51.1320
5600	4.9716	27.8516	296.9212	51.2216
5700	4.9722	28.3487	297.4183	51.3096
5800	4.9728	28.8460	297.9156	51.3961
5900	4.9736	29.3433	298.4129	51.4811
6000	4.9745	29.8407	298.9103	51.5647

TABLE XIII—THERMODYNAMIC PROPERTIES OF B₁ (GAS)

[Molecular weight, 21.64]

T (°K)	C _p (cal mole °K)	H _T - H ₀ (kcal mole)	H _T (kcal mole)	S _T (cal mole °K)	$\frac{\Delta H^c}{RT}$	$\delta \left(-\frac{\Delta H^c}{RT} \right) = \frac{-\delta T}{100} \left(\frac{a}{T} + b \right)$		log K	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c}{T} + d \right)$	
						a	b		c	d
0	7.289	0	463.8652	48.662	118.8190	—	—	46.2160	—	—
298.16	7.295	2.0934	470.7386	48.667	118.0983	—	—	46.8935	—	—
300	7.295	2.1068	470.7720	48.667	118.0983	—	—	33.0462	—	—
400	7.645	2.8540	471.5192	50.844	88.8842	—	—	21.3221	—	—
500	7.950	3.6338	472.2980	52.054	71.3228	—	—	—	—	—
600	8.165	4.4398	473.1050	54.062	59.5032	—	—	20.1558	—	—
700	8.380	5.2046	473.9298	55.323	51.2012	—	—	16.4542	—	—
800	8.460	6.1042	474.7694	55.444	44.8980	—	—	13.6715	—	—
900	8.540	6.9357	475.6189	57.445	39.9899	—	—	11.5032	—	—
1000	8.608	7.8116	476.4767	58.348	36.0593	8426	0.01325	9.7646	1562	0.01399
1100	8.665	8.6751	477.3403	59.1711	32.8406	2209	0.01003	8.8397	1413	0.01210
1200	8.704	9.5438	478.2088	59.6267	30.1564	2044	.00708	7.1901	1296	.01138
1300	8.738	10.4157	479.0809	60.6248	27.8868	2720	.00624	6.1418	1198	.00998
1400	8.764	11.2898	479.9860	61.2732	25.9347	2528	.00467	5.2761	1113	.00940
1500	8.784	12.1652	480.8534	61.8786	24.2447	2359	.00502	4.5247	1040	.00860
1600	8.808	13.0475	481.7127	62.4461	22.7863	2213	0.00404	3.8661	976	0.00788
1700	8.820	13.9267	482.5939	62.0803	21.4596	2084	.00342	3.2241	919	.00764
1800	8.832	14.8113	483.4765	63.4945	20.2983	1989	.00288	2.7659	869	.00683
1900	8.842	15.6950	484.3602	63.9626	19.2591	1886	.00260	2.2016	824	.00650
2000	8.852	16.5797	485.2449	64.4161	18.3225	1774	.00184	1.8831	784	.00597
2100	8.860	17.4653	486.1305	64.8484	17.4780	1690	0.00172	1.5038	747	0.00565
2200	8.868	18.3517	487.0169	65.2608	16.7070	1614	.00136	1.1886	714	.00527
2300	8.874	19.2388	487.9040	65.6551	16.0339	1544	.00127	.8429	683	.00522
2400	8.880	20.1265	488.7917	66.0329	15.3593	1480	.00120	.5531	656	.00500
2500	8.884	21.0147	489.6799	66.3955	14.7661	1421	.00106	.2861	630	.00449
2600	8.888	21.9033	490.5685	66.7440	14.2185	1367	0.00080	0.0393	606	0.00446
2700	8.891	22.7922	491.4574	67.0795	13.7114	1316	.00090	—1.98	584	.00423
2800	8.895	23.6815	492.3467	67.4029	13.2495	1270	.00067	—4024	564	.00393
2900	8.898	24.5712	493.2364	67.7151	12.8019	1228	.00063	—6608	545	.00383
3000	8.901	25.4611	494.1263	68.0168	12.3926	1185	.00074	—7863	527	.00370
3100	8.903	26.3513	495.0165	68.3057	12.0096	1147	0.00068	—0.9600	511	0.00341
3200	8.906	27.2418	495.9070	68.6914	11.6505	1111	.00063	—1.1231	495	.00340
3300	8.908	28.1325	496.7977	69.8856	11.3152	1078	.00054	—1.2785	481	.00323
3400	8.910	29.0234	497.6886	69.1314	10.9956	1046	.00054	—1.4212	466	.00336
3500	8.912	29.9145	498.5797	69.3896	10.6962	1016	.00058	—1.5577	453	.00327
3600	8.915	30.8058	499.4710	69.6409	10.4134	988	0.00057	—1.6803	441	0.00311
3700	8.917	31.6974	500.3626	69.8842	10.1458	961	.00051	—1.8041	429	.00311
3800	8.919	32.5892	501.2544	70.1230	9.8923	936	.00050	—1.9251	419	.00286
3900	8.921	33.4812	502.1464	70.3547	9.6518	912	.00060	—2.0354	408	.00280
4000	8.923	34.3734	503.0383	70.5806	9.4232	889	.00057	—2.1402	398	.00283
4100	8.925	35.2658	503.9310	70.8009	9.2058	867	0.00057	—2.2401	388	0.00268
4200	8.927	36.1584	504.8236	71.0160	8.9897	847	.00052	—2.3344	380	.00263
4300	8.930	37.0513	505.7165	71.2261	8.8012	827	.00055	—2.4263	371	.00258
4400	8.932	37.9444	506.6096	71.4314	8.6127	808	.00054	—2.5132	363	.00253
4500	8.935	38.8377	507.5029	71.6322	8.4326	780	.00068	—2.5964	355	.00253
4600	8.937	39.7313	508.3965	71.8286	8.2602	773	0.00063	—2.6761	348	0.00226
4700	8.940	40.6252	509.2904	72.0243	8.0951	756	.00070	—2.7525	341	.00226
4800	8.944	41.5194	510.1846	72.2091	7.9369	740	.00078	—2.8258	334	.00224
4900	8.947	42.4139	511.0791	72.3935	7.7851	724	.00090	—2.8962	327	.00220
5000	8.951	43.3068	511.9740	72.5743	7.6394	710	.00088	—2.9638	321	.00216
5100	8.955	44.2041	512.8663	72.7516	7.4903	695	0.00105	—3.0289	315	0.00212
5200	8.959	45.0985	513.7580	72.9285	7.3646	682	.00102	—3.0918	309	.00210
5300	8.963	45.9929	514.6511	73.0962	7.2349	669	.00101	—3.1520	303	.00209
5400	8.968	46.8925	515.5577	73.2638	7.1100	656	.00118	—3.2102	298	.00202
5500	8.973	47.7895	516.4547	73.4284	6.9898	644	.00110	—3.2664	293	.00188
5600	8.979	48.6871	517.3523	73.5901	6.9735	632	0.00122	—3.3206	288	0.00187
5700	8.985	49.5853	518.2505	73.7491	6.7614	620	.00130	—3.3730	283	.00191
5800	8.991	50.4841	519.1493	73.9054	6.6552	610	.00131	—3.4237	278	.00188
5900	8.998	51.3836	520.0485	74.0592	6.5455	599	.00137	—3.4727	273	.00190
6000	9.005	52.2837	520.9489	74.2105	6.4473	—	—	—3.5201	—	—

TABLE XIV—THERMODYNAMIC PROPERTIES OF BF₃ (GAS)

[Molecular weight, 29.82]

T (°K)	C_p (cal/mole·°K)	$H_T^o - H_0^o$ (kcal/mole)	H_T^o (kcal/mole)	S_T^o (cal/mole·°K)	$\frac{\Delta H^o}{RT}$	$\delta \left(\frac{-\Delta H^o}{RT} \right) - \frac{-\delta T}{100} \left(\frac{a}{T} + b \right)$		$\log K$	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c}{T} + d \right)$	
						a	b		c	d
0		0	218.1759					67.5587		
208.18	7.0696	2.0789	220.2548	47.9001	169.0481					
300	7.0729	2.0919	220.2678	47.9437	168.0215			67.1285		
400	7.3044	2.8101	220.9860	60.0081	126.4173			48.8690		
500	7.5718	3.6639	221.7298	61.6668	101.4208			37.8738		
600	7.8149	4.8236	222.4995	53.0604	84.7288			30.6239		
700	8.0158	5.1155	223.2914	54.2897	72.7858			25.2615		
800	8.1760	5.9224	224.1018	55.3710	63.8146			21.3064		
900	8.3024	6.7495	224.9255	56.3416	56.8273			18.2243		
1000	8.4025	7.5850	225.7609	57.2217	51.2304	5016	0.02420	15.7542	2207	0.01784
1100	8.4822	8.4293	226.6063	58.0284	46.0462	4665	0.01963	18.739C	2009	0.01623
1200	8.5464	9.2809	227.4568	58.7673	42.9224	4189	0.01589	12.0406	1844	0.01304
1300	8.5986	10.1882	228.3142	59.4585	39.5842	3870	0.01341	10.6091	1704	0.01106
1400	8.6415	11.0003	229.1762	60.0924	36.8065	3597	0.01100	9.3803	1584	0.01040
1500	8.6770	11.8663	230.0422	60.6898	34.3975	3360	0.00900	8.3139	1480	0.00920
1600	8.7063	12.7355	230.9115	61.2508	32.2885	3182	0.00778	7.8797	1388	0.00883
1700	8.7319	13.6075	231.7834	61.7794	30.4268	2969	0.00638	6.5544	1208	0.00759
1800	8.7583	14.4818	232.6577	62.2791	28.7708	2805	0.00588	5.8198	1230	0.00747
1900	8.7717	15.3680	233.5340	62.7529	27.2856	2659	0.00500	5.1618	1173	0.00690
2000	8.7875	16.2360	234.4120	63.2032	26.0541	2528	0.00309	4.5689	1115	0.00616
2100	8.8013	17.1155	235.2014	63.6323	24.7463	2408	0.00376	4.0318	1062	0.00597
2200	8.8133	17.9982	236.1722	64.0420	23.6420	2306	0.00310	3.5431	1015	0.00550
2300	8.8239	18.8781	237.0540	64.4340	22.0449	2201	0.00232	3.0363	971	0.00512
2400	8.8332	19.7610	237.9369	64.8098	21.7250	2116	0.00240	2.6863	931	0.00520
2500	8.8415	20.6447	238.8206	65.1705	20.8768	2026	0.00227	2.3087	894	0.00506
2600	8.8489	21.5292	239.7052	65.1575	20.0971	1949	0.00195	1.9508	860	0.00496
2700	8.8555	22.4145	240.5904	65.8516	18.3783	1877	0.00184	1.6363	829	0.00453
2800	8.8614	23.3003	241.4763	66.1737	18.7011	1811	0.00152	1.3257	801	0.00399
2900	8.8668	24.1867	242.3626	66.4848	18.0781	1749	0.00130	1.0555	774	0.00380
3000	8.8716	25.0736	243.2496	66.7856	17.4908	1691	0.00122	7.7937	749	0.00359
3100	8.8760	26.9610	244.1370	67.0764	16.9440	1637	0.00104	0.5485	725	0.00334
3200	8.8800	26.8483	245.0248	67.3583	16.4314	1586	0.00099	.3184	703	0.00327
3300	8.8837	27.7370	248.9130	68.6316	15.9498	1538	0.00105	.1021	682	0.00321
3400	8.8870	28.0256	246.8015	67.8969	15.4964	1498	0.00083	-1.1017	662	0.00326
3500	8.8901	29.5144	247.6804	68.1545	15.0639	1451	0.00084	-2.2441	644	0.00301
3600	8.8929	30.4036	248.5795	68.4050	14.6650	1411	0.00068	-0.4780	620	0.00301
3700	8.8955	31.2930	249.4690	68.6487	14.2830	1378	0.00068	-1.6482	610	0.00287
3800	8.8979	32.1827	250.3588	68.8860	13.9210	1337	0.00058	-2.8116	593	0.00235
3900	8.9001	33.0726	251.2455	69.1171	13.5776	1303	0.00055	-3.9686	579	0.00225
4000	8.9022	33.9627	252.1386	69.3425	13.2613	1270	0.00074	-1.1141	565	0.00270
4100	8.9041	34.8530	253.0290	69.5622	12.9408	1239	0.00060	-1.2546	551	0.00261
4200	8.9059	35.7435	253.9195	69.7759	12.6462	1210	0.00050	-1.3884	538	0.00268
4300	8.9075	36.6342	254.8101	69.8865	12.3033	1182	0.00056	-1.5162	526	0.00255
4400	8.9091	37.5250	255.7009	70.1913	12.0941	1155	0.00053	-1.6383	514	0.00258
4500	8.9105	38.4160	256.5920	70.3915	11.8369	1129	0.00057	-1.7551	503	0.00245
4600	8.9119	39.3071	257.4830	70.5874	11.5909	1105	0.00049	-1.8609	492	0.00232
4700	8.9132	40.1983	258.3743	70.7790	11.3568	1082	0.00038	-1.9741	482	0.00228
4800	8.9144	41.0897	259.2657	70.9667	11.1285	1060	0.00017	-2.0769	472	0.00227
4900	8.9155	41.9812	260.1571	71.1505	10.9130	1039	0.00020	-2.1758	463	0.00230
5000	8.9165	42.8728	261.0487	71.3306	10.7050	1018	0.00019	-2.2704	454	0.00218
5100	8.9175	43.7645	261.9406	71.5072	10.5052	998	0.00018	-2.3816	445	0.00222
5200	8.9184	44.6563	262.8229	71.6904	10.3121	979	0.00009	-2.4494	437	0.00205
5300	8.9193	45.5483	263.7242	71.8803	10.1233	960	0.00022	-2.5339	429	0.00206
5400	8.9202	46.4402	264.6161	72.0170	9.9503	943	0.00015	-2.6164	421	0.00205
5500	8.9210	47.3323	265.5082	72.1807	9.7787	926	0.00004	-2.6940	414	0.00197
5600	8.9217	48.2244	266.4003	72.3414	9.6133	910	0.00005	-2.7699	407	0.00190
5700	8.9224	49.1166	267.2926	72.4994	9.4536	894	-0.00004	-2.8432	400	0.00183
5800	8.9231	50.0089	268.1848	72.6543	9.2995	879	-0.00008	-2.9140	393	0.00179
5900	8.9237	50.9013	269.0771	72.8071	9.1506	864	-0.00010	-2.9824	387	0.00180
6000	8.9244	51.7938	269.8696	72.9571	9.0067	-----	-0.00017	-3.0487	380	0.00178

TABLE XV—THERMODYNAMIC PROPERTIES OF BF₃ (GAS)

[Molecular weight, 67.82]

<i>T</i> (°K)	<i>C_p</i> (cal mole °K)	<i>H₂^o - H₂^g</i> (kcal mole)	<i>H₂^g</i> (kcal mole)	<i>S₂^o</i> (cal mole °K)	$-\frac{\Delta H^o}{RT}$	$\delta\left(-\frac{\Delta H^o}{RT}\right) = \frac{-\delta T}{100} \left(\frac{a}{T} + b\right)$	log <i>K</i>	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c}{T} + d\right)$	
								<i>a</i>	<i>b</i>
0	0	0	0	0	0	0	0	0	0
298.18	12.0621	2.7842	2.7842	60.6858	704.3124	0	286.2741	0	0
300	12.0631	2.8068	2.8068	60.7712	700.0296	0	284.3881	0	0
400	13.7643	4.1030	4.1030	64.4994	526.0482	0	208.3238	0	0
500	15.0594	5.5471	5.5471	67.7061	421.4916	0	162.5976	0	0
600	16.0430	7.1046	7.1046	70.5493	351.6741	0	132.0708	0	0
700	16.7819	8.7482	8.7482	78.0755	301.7803	0	110.2416	0	0
800	17.3580	10.4570	10.4570	75.3564	264.2235	0	93.3852	0	0
900	17.7815	12.2154	12.2154	77.4270	235.0185	0	81.1010	0	0
1000	18.1277	14.0120	14.0120	79.3197	211.6314	20.979	70.8915	9168	0.02195
1100	18.3922	15.8380	15.8380	81.0398	192.4805	19.069	62.5341	8339	0.0123
1200	18.6030	17.6378	17.6378	82.6892	178.5095	17.513	55.6667	7648	0.01462
1300	18.7781	19.5666	19.5666	84.1860	162.9868	16.178	49.8990	7068	0.01180
1400	18.9122	21.4409	21.4409	85.5613	151.3993	16.083	44.6122	6561	0.00970
1500	19.0270	23.3878	23.3878	86.8700	141.3330	14.039	40.2285	6126	0.00795
1600	19.1228	25.8453	25.2453	88.1010	132.5298	13.169	36.3918	5745	0.00609
1700	19.2035	27.1616	27.1616	89.2628	124.7501	12.400	33.0067	5409	0.00540
1800	19.2720	29.0854	29.0854	90.3628	117.8483	11.717	29.9833	5110	0.00443
1900	19.3306	31.0155	31.0155	91.4059	111.6650	11.105	27.3014	4842	0.00400
2000	19.3818	32.9511	32.9511	92.3887	106.0973	10.634	24.8784	4601	0.00335
2100	19.4252	34.8915	34.8915	93.3454	101.0585	10.035	22.6821	4383	0.00253
2200	19.4635	36.8389	36.8389	94.2499	96.4787	9.601	20.8870	4184	0.00267
2300	19.4971	38.7839	38.7839	95.1159	92.2924	8.138	18.8552	4003	0.00226
2400	19.5268	40.7361	40.7361	96.9448	88.4580	8.808	17.1959	3837	0.00190
2500	19.5522	42.6891	42.6891	96.7440	84.9288	8.488	15.6383	3654	0.00165
2600	19.5766	44.6456	44.6456	97.5113	81.6666	8.138	14.2397	3543	0.00148
2700	19.5976	46.6043	46.6043	98.2305	78.0453	7.838	12.9260	3412	0.00133
2800	19.6165	48.5650	48.5650	98.9836	75.8452	7.565	11.7061	3291	0.00107
2900	19.6332	50.5275	50.5275	99.6622	73.2350	7.298	10.5702	3178	0.00087
3000	19.6486	52.4916	52.4916	100.3181	70.7985	7.054	9.5100	3072	0.00083
3100	19.6626	54.4572	54.4572	100.9626	68.5189	6.827	8.5182	2973	0.00094
3200	19.6753	56.4241	56.4241	101.5871	66.3815	6.615	7.5882	2880	0.00087
3300	19.6867	58.3922	58.3922	102.1927	64.3735	6.416	6.7146	2793	0.00083
3400	19.6972	60.3614	60.3614	102.7805	62.4834	6.228	5.8923	2711	0.00083
3500	19.7069	62.3316	62.3316	103.3416	60.7011	6.051	5.1169	2634	0.00063
3600	19.7168	64.3027	64.3027	103.9069	59.0177	5.884	4.8846	2561	0.00054
3700	19.7240	66.2747	66.2747	104.4472	57.4251	5.725	3.9919	2492	0.00051
3800	19.7316	68.2475	68.2475	104.9738	55.9182	5.575	3.0336	2427	0.00039
3900	19.7386	70.2210	70.2210	105.4860	54.4848	5.488	2.4129	2365	0.00035
4000	19.7451	72.1952	72.1952	105.9888	53.1245	5.298	1.8213	2306	0.00026
4100	19.7511	74.1700	74.1700	106.4784	51.8306	5.189	1.2586	2260	0.00029
4200	19.7567	76.1454	76.1454	106.9494	50.5982	5.046	0.00169	7226	0.00030
4300	19.7619	78.1213	78.1213	107.4144	49.4221	4.929	-0.00187	2116	0.00030
4400	19.7688	80.0977	80.0977	107.8688	48.3013	4.817	0.00146	-2762	0.00020
4500	19.7714	82.0746	82.0746	108.3130	47.2294	4.711	0.00127	-724	0.00025
4600	19.7737	84.0519	84.0519	108.7476	46.2040	4.609	-1.1833	2006	0.00019
4700	19.7777	86.0295	86.0295	109.1720	45.2222	4.512	-1.6153	1963	0.00014
4800	19.7814	88.0074	88.0074	109.5893	44.2812	4.418	-2.0244	1922	0.00026
4900	19.7849	89.9857	89.9857	109.9972	43.3786	4.328	-2.4169	1883	0.00020
5000	19.7882	91.9644	91.9644	110.3970	42.5121	4.242	-2.7937	1848	0.00016
5100	19.7913	93.9434	93.9434	110.7889	41.6795	4.159	-3.1557	1809	0.00022
5200	19.7942	95.9226	95.9226	111.1732	40.8789	4.079	-3.5038	1775	0.00009
5300	19.7969	97.9022	97.9022	111.5603	40.1085	4.002	-3.8388	1741	0.00018
5400	19.7995	99.8820	99.8820	111.9204	39.3668	3.929	-4.1814	1708	0.00025
5500	19.8020	101.8621	101.8621	112.2887	38.6516	3.857	-4.4722	1673	0.00016
5600	19.8044	103.8424	103.8424	112.6405	37.9622	3.789	-4.7720	1648	0.00008
5700	19.8067	105.8220	105.8220	112.9910	37.2369	3.722	-5.0612	1619	0.00016
5800	19.8089	107.8037	107.8037	113.3355	36.6546	3.659	-5.3405	1591	0.00014
5900	19.8110	109.7847	109.7847	113.6742	36.0340	3.597	-5.6108	1564	0.00013
6000	19.8131	111.7659	111.7659	114.0072	35.4341	-----	-5.8711	-----	-----

TABLE XVI—THERMODYNAMIC PROPERTIES OF BH (GAS)

[Molecular weight, 11.828]

T (°K)	C_p (cal mole °K)	$H_r^{\circ} - H_0^{\circ}$ (kcal mole)	H_r° (kcal mole)	S_r° (cal mole °K)	$\frac{\Delta H^{\circ}}{RT}$	$\delta \left(\frac{\Delta H^{\circ}}{RT} \right) = \frac{-\delta T}{100} \left(\frac{a}{T} + b \right)$	$\log K$	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c}{T} + d \right)$
								a b c d
0	6.9368	0	279.8258	41.0362	127.4086	.....	60.3050	.....
298.16	6.9368	2.0739	281.8997	41.0362	126.6364	.....	49.9656	.....
300	6.9368	2.0867	281.9126	41.0790	126.6364	.....	46.1918	.....
400	6.9931	2.7839	282.6097	43.0847	95.8504	.....	27.8950	.....
500	7.0793	3.4871	283.3129	44.6534	76.8727	.....	.....	.....
600	7.2120	4.2014	284.0272	45.9554	64.0449	.....	22.3429	.....
700	7.3713	4.9205	284.7568	47.0790	55.0888	.....	18.3628	.....
800	7.5344	5.6768	285.5016	48.0740	48.3563	.....	15.3677	.....
900	7.6897	6.4371	286.2629	48.7056	43.1123	.....	13.0308	.....
1000	7.8309	7.2183	287.0391	49.7881	38.9114	37.64	0.03127	11.1568
1100	7.9561	8.0026	287.8284	50.5404	35.4674	2417	0.02740	9.6176
1200	8.0656	8.8037	288.6295	51.2378	32.5925	3136	.02419	8.8324
1300	8.1607	9.6160	289.4408	51.8867	30.1860	2899	.02089	7.2423
1400	8.2431	10.4562	290.2610	52.4945	28.0544	2686	.01607	6.3058
1500	8.3144	11.2681	291.0889	53.0556	26.2490	2520	.01550	5.4924
1600	8.3784	12.0676	291.9234	53.6042	24.6585	2366	0.01344	4.7702
1700	8.4302	12.8380	292.7638	54.1136	23.2823	2229	.01217	4.1456
1800	8.4772	13.7833	293.6091	54.9498	22.0028	2108	.01038	3.5871
1900	8.5184	14.6331	294.4689	55.0862	20.8830	2000	.00900	3.0837
2000	8.5546	15.4668	295.3126	55.4941	19.8740	1902	.00789	2.6298
2100	8.5886	16.3438	296.1626	55.9123	18.9804	1818	0.00721	2.2185
2200	8.6150	17.2039	297.0297	54.3124	18.1291	1733	.00612	1.8439
2300	8.6401	18.0687	297.8925	54.6950	17.2895	1659	.00555	1.5013
2400	8.6626	18.9318	298.7576	57.0641	16.6727	1591	.00510	1.1867
2500	8.6828	19.7991	299.6249	57.4181	16.0312	1529	.00442	.8969
2600	8.7009	20.6683	300.4941	57.7590	15.4387	1471	0.00409	0.6289
2700	8.7172	21.5392	301.3680	58.0877	14.8898	1418	.00357	.3803
2800	8.7320	22.4116	302.2374	58.4060	14.3798	1358	.00338	.1492
2900	8.7453	23.3855	303.1113	58.7116	13.9047	1322	.00293	.509
3000	8.7575	24.1606	303.9864	59.0082	13.4611	1279	.00262	.2677
3100	8.7886	25.0369	304.8627	59.2956	12.0450	1238	0.00252	-0.4564
3200	8.7778	25.9143	305.7401	59.5742	12.6565	1200	.00236	-0.3336
3300	8.7881	26.7926	306.6184	59.8445	12.2905	1164	.00225	-0.8003
3400	8.7966	27.6719	307.4977	60.1070	11.9450	1130	.00204	-0.9574
3500	8.8045	28.5519	308.3777	60.3621	11.6210	1099	.00182	-1.1057
3600	8.8117	29.4327	309.2585	60.6102	11.3139	1068	0.00185	-1.2460
3700	8.8184	30.3143	310.1401	60.8817	11.0284	1040	.00162	-1.3789
3800	8.8246	31.1964	311.0222	61.0870	10.7481	1018	.00156	-1.5050
3900	8.8304	32.0782	311.9050	61.3163	10.4968	988	.00130	-1.6248
4000	8.8357	32.9625	312.7888	61.5399	10.2385	964	.00118	-1.7387
4100	8.8407	33.8463	313.6721	61.7581	10.0022	940	0.00119	-1.8472
4200	8.8463	34.7206	314.5564	61.9712	9.7772	918	.00111	-1.9507
4300	8.8497	35.6158	315.4411	62.1794	9.5626	897	.00114	-2.0495
4400	8.8537	36.5005	316.3268	62.3829	9.3576	877	.00091	-2.1440
4500	8.8575	37.3861	317.2119	62.5819	9.1618	858	.00068	-2.2343
4600	8.8611	38.2720	318.0978	62.7766	8.9744	840	0.00078	-2.3209
4700	8.8644	39.1583	318.9841	62.9672	8.7949	822	.00075	-2.4039
4800	8.8676	40.0449	319.8707	63.1539	8.6229	805	.00072	-2.4835
4900	8.8705	40.9318	320.7576	63.3368	8.4579	789	.00060	-2.5600
5000	8.8738	41.8190	321.6448	63.5160	8.2995	774	.00054	-2.6335
5100	8.8769	42.7064	322.5222	63.6918	8.1472	768	0.00063	-2.7042
5200	8.8784	43.5941	323.4199	63.8641	8.0008	744	.00052	-2.7723
5300	8.8807	44.4821	324.3079	64.0333	7.8599	730	.00052	-2.8379
5400	8.8830	45.3703	325.1961	64.1993	7.7242	717	.00044	-2.9011
5500	8.8850	46.2687	326.0845	64.3623	7.5934	704	.00039	-2.9622
5600	8.8870	47.1473	326.9731	64.5224	7.4678	692	0.00040	-3.0211
5700	8.8889	48.0361	327.8619	64.6797	7.3456	680	.00026	-3.0780
5800	8.8907	48.9251	328.7509	64.8343	7.2280	668	.00028	-3.1381
5900	8.8924	49.8142	329.6400	64.9863	7.1145	657	.00030	-3.1863
6000	8.8941	50.7035	330.5293	65.1358	7.0047	.....	-3.2378	.....

TABLE XVII—THERMODYNAMIC PROPERTIES OF BO (GAS)

[Molecular weight, 26.82]

T (°K)	C _b (cal mole °K)	H _T - H ₀ (kcal mole)	H _T (kcal mole)	S _T (cal mole °K)	$\frac{\Delta H^o}{RT}$	$\delta \left(\frac{\Delta H^o}{RT} \right) = \frac{-\delta T}{100} \left(\frac{a}{T} + b \right)$	log K	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c}{T} + d \right)$	
								c	d
0	-----	0	168.1616	-----	272.6696	-----	112.6245	-----	-----
200	16	6.976	2.0731	170.2247	48.805	272.6696	-----	111.5980	-----
300	6.977	2.0739	2.0739	170.2475	48.847	271.0072	-----	82.4477	-----
400	7.062	2.7872	170.9488	50.664	203.6499	-----	64.7442	-----	-----
500	7.230	3.8018	171.6634	52.269	163.2146	-----	-----	-----	-----
600	7.427	4.2847	172.3863	53.594	138.2389	-----	138.9207	-----	-----
700	7.635	4.9830	173.1496	54.755	116.9540	-----	44.4620	-----	-----
800	7.810	5.7600	173.9216	55.785	102.4775	-----	33.1086	-----	-----
900	7.970	6.5430	174.7106	56.714	91.2079	-----	33.1604	-----	-----
1000	8.109	7.3530	175.5146	57.863	82.1842	8094	0.030362	29.1974	3847 0.02185
1100	8.225	8.1697	176.3313	58.3413	74.7981	7263	0.02847	25.9509	3229 0.01747
1200	8.325	8.9972	177.1888	59.0618	68.6328	6754	0.02952	23.2426	2963 0.01467
1300	8.411	9.8340	177.9956	59.7210	63.4149	6239	0.01907	20.9487	2371 0.01310
1400	8.485	10.6788	178.8404	60.3570	58.9394	5797	0.01653	18.9806	2344 0.01120
1500	8.545	11.5305	179.6921	60.9446	55.0582	5414	0.01425	17.2734	2378 0.01010
1600	8.6025	12.3881	180.5497	61.4980	51.6602	5079	0.01195	15.7783	2229 0.00912
1700	8.6483	13.2506	181.4122	62.0209	48.6806	4788	0.01048	14.4580	2069 0.00839
1800	8.6883	14.1174	182.2790	62.5164	45.9292	4520	0.00685	13.2835	1984 0.00749
1900	8.7285	14.9836	183.1496	62.9871	43.6051	4284	0.00700	12.2318	1880 0.00720
2000	8.7650	15.8620	184.0236	63.4354	41.4552	4071	0.00733	11.2646	1787 0.00665
2100	8.7836	16.7380	184.9005	63.8632	39.5093	3879	0.00632	10.4270	1703 0.00611
2200	8.8095	17.6185	185.7801	64.2744	37.7398	3704	0.00587	9.6488	1627 0.00551
2300	8.8333	18.5007	186.6622	64.6645	36.1285	3545	0.00492	8.9339	1556 0.00547
2400	8.8549	19.3851	187.5467	65.0409	34.6115	3398	0.00460	8.2801	1493 0.00450
2500	8.8749	20.2716	188.4332	65.4028	33.2777	3264	0.00382	7.5781	1434 0.00456
2600	8.8934	21.1600	189.3216	65.7518	32.0185	3140	0.00324	7.1220	1379 0.00436
2700	8.9106	22.0502	190.2118	66.0572	30.5623	3024	0.00320	6.6689	1329 0.00406
2800	8.9268	22.9421	191.1037	66.4116	29.7691	2918	0.00249	6.1282	1262 0.00393
2900	8.9421	23.8356	191.9971	66.7261	28.7804	2818	0.00217	5.6822	1228 0.00363
3000	8.9565	24.7304	192.8920	67.0285	27.5189	2725	0.00197	5.2657	1197 0.00367
3100	8.9702	25.6268	193.7884	67.3224	26.9379	2638	0.00182	4.8769	1189 0.00351
3200	8.9833	26.5244	194.6660	67.6074	26.1119	2557	0.00115	4.5102	1124 0.00319
3300	8.9959	27.4234	195.5350	67.8840	25.3369	2480	0.00109	4.1884	1090 0.00311
3400	9.0081	28.3236	196.4152	68.1527	24.6054	2408	0.00070	3.8427	1058 0.00311
3500	9.0200	29.2280	197.3666	68.4140	23.9187	2340	0.00060	3.5373	1028 0.00304
3600	9.0316	30.1276	198.2692	68.6683	22.6681	2275	0.00054	3.2487	1000 0.00293
3700	9.0430	31.0313	199.1929	68.9169	22.0607	2214	0.00087	2.9755	973 0.00255
3800	9.0543	31.9302	200.0978	69.1572	22.0677	2157	0.00012	2.7166	948 0.00272
3900	9.0654	32.8422	201.0038	69.3925	21.5145	2102	0.00000	2.4705	924 0.00270
4000	9.0763	33.7492	201.9108	69.6222	20.9890	2050	-0.00020	2.2871	901 0.00264
4100	9.0870	34.6574	202.8190	69.8464	20.4892	2000	-0.00009	2.0147	879 0.00261
4200	9.0976	35.5666	203.7282	70.0665	20.0131	1953	-0.00029	1.8025	859 0.00243
4300	9.1080	36.4769	204.6385	70.2797	19.5592	1908	-0.00044	1.6008	839 0.00242
4400	9.1183	37.3882	205.5498	70.4892	19.1260	1865	-0.00044	1.4075	820 0.00238
4500	9.1284	38.3006	206.4822	70.6943	18.7120	1824	-0.00062	1.2229	802 0.00235
4600	9.1384	39.2139	207.3755	70.8950	18.3161	1785	-0.00069	1.0462	785 0.00238
4700	9.1482	40.1282	208.2898	71.0916	17.9370	1747	-0.00076	.8768	768 0.00230
4800	9.1579	41.0325	209.2051	71.2843	17.5738	1710	-0.00058	.7145	753 0.00213
4900	9.1675	41.9508	210.1214	71.4733	17.2254	1678	-0.00070	.5887	738 0.00210
5000	9.1769	42.8770	211.0386	71.6536	16.8909	1642	-0.00068	.4090	722 0.00223
5100	9.1862	43.7952	211.9568	71.8404	16.5696	1610	-0.00072	.2652	709 0.00215
5200	9.1954	44.7148	212.8759	72.0189	16.2807	1580	-0.00091	.1267	685 0.00217
5300	9.2045	45.6343	213.7959	72.1941	16.9638	1550	-0.00084	.0666	662 0.00210
5400	9.2138	46.5552	214.7168	72.3662	16.6773	1521	-0.00085	.1350	669 0.00216
5500	9.2224	47.4770	215.6386	72.5354	16.4016	1494	-0.00099	.2568	657 0.00218
5600	9.2312	48.8906	216.5613	72.7016	16.1368	1467	-0.00077	.3738	645 0.00214
5700	9.2399	49.3232	217.4848	72.8681	15.8782	1441	-0.00085	.4936	634 0.00219
5800	9.2485	50.2476	218.4092	73.0269	15.6316	1416	-0.00080	.6051	623 0.00211
5900	9.2570	51.1729	219.3345	73.1840	15.3924	1393	-0.00067	.7125	612 0.00220
6000	9.2654	52.0990	220.2606	73.3397	15.1612	-----	-0.8170	-----	-----

TABLE XVIII—THERMODYNAMIC PROPERTIES OF B_2O_3 (GAS)

[Molecular weight, 69.64]

T (°K)	C_p^o (cal/mole °K)	$H_T^o - H_0^o$ (kcal/mole)	H_T^o (kcal/mole)	S_T^o (cal/mole °K)	$\frac{\Delta H^o}{RT}$	$s\left(-\frac{\Delta H^o}{RT}\right) - \frac{-\delta T}{100}\left(\frac{a}{T} + b\right)$	$\log K$	$\delta \log K = \frac{-\delta T}{100}\left(\frac{c}{T} + d\right)$	
								c	d
0		0	126.6839						
298.16		0	126.6839						
300									
400									
500									
600									
700									
800									
900									
1000	28.360	16.5945	142.6834	82.1636	301.8037	29.998	0.10329	101.1271	13.090
1100	28.754	18.9502	148.0391	86.4085	274.4295	27.265	0.08117	89.2101	11.905
1200	24.084	21.3411	147.4300	88.4586	261.6025	26.041	0.0409	79.2773	10.917
1300	24.311	23.7599	149.8488	98.4246	232.2761	23.181	0.0178	70.8714	10.081
1400	24.510	26.2009	152.2898	90.2385	215.7022	21.492	0.0230	68.6657	9.363
1500	24.672	28.6600	154.7459	91.9300	201.3319	20.071	0.0342	57.4203	8.741
1600	24.806	31.1339	157.2228	92.5266	188.7531	18.825	0.02917	51.8554	8.196
1700	24.916	28.6199	159.7088	95.0337	177.6504	17.726	0.0242	47.1333	7.715
1800	25.010	30.1162	162.2051	96.4605	167.7784	16.748	0.02046	42.8471	7.287
1900	25.090	38.6212	164.7101	97.3148	158.9432	15.872	0.01760	39.0121	6.904
2000	25.159	41.1337	167.2226	99.1036	150.9896	15.083	0.00865	35.5606	6.560
2100	25.221	43.6527	169.7416	100.8326	143.7919	14.368	0.01369	32.4833	6.248
2200	25.277	46.1776	172.2865	101.6071	137.2473	13.718	0.01235	29.5939	5.965
2300	25.329	48.7079	174.7988	102.6319	131.2706	13.127	0.00932	27.0084	5.706
2400	25.374	51.2430	177.3319	103.7108	125.7011	12.587	0.00710	24.6331	5.483
2500	25.408	53.7821	179.8710	104.7473	120.7492	12.087	0.00865	22.4480	5.249
2600	25.429	56.3245	182.4134	105.7445	116.0947	11.626	0.00418	20.4311	5.047
2700	25.466	58.8697	184.9586	106.7050	111.7846	11.197	0.00367	18.5638	4.861
2800	25.491	61.4178	187.5065	107.8316	107.7820	10.502	0.00177	16.8300	4.687
2900	25.514	63.0678	190.0887	108.5266	104.0554	10.432	0.00097	16.2160	4.525
3000	25.534	66.5202	192.6091	109.3919	100.5771	10.087	0.00003	13.7097	4.374
3100	25.552	69.0745	195.1684	110.2294	97.3232	9.764	-0.00065	12.3008	4.233
3200	25.570	71.6306	197.7195	111.0409	94.2726	9.463	-0.0197	10.9800	4.100
3300	25.585	74.1884	200.2773	111.3280	91.4070	9.178	-0.0261	9.7394	3.976
3400	25.598	76.7476	202.8385	112.5920	88.7102	8.910	-0.0301	8.5719	3.858
3500	25.618	79.3082	205.3971	113.3842	86.1676	8.659	-0.0418	7.4712	3.748
3600	25.624	81.8700	207.9589	114.0560	83.7664	8.420	-0.00447	6.4817	3.644
3700	25.635	84.4330	210.5219	114.7582	81.4952	8.195	-0.00528	5.4495	3.545
3800	25.646	86.9970	213.0859	115.4419	79.8439	7.980	-0.00533	4.5172	3.452
3900	25.655	89.5620	215.6509	116.1082	77.3031	7.779	-0.00635	3.9336	3.382
4000	25.663	92.1279	218.2168	116.7578	75.8047	7.585	-0.00640	2.7944	3.278
4100	25.671	94.6046	220.7835	117.3916	73.6211	7.401	-0.00864	1.9961	3.198
4200	25.679	97.2621	223.3510	118.0103	71.7556	7.226	-0.00846	1.2859	3.122
4300	25.687	99.8304	225.9193	118.6147	70.0921	7.060	-0.00755	.5111	3.049
4400	25.693	102.3994	228.4883	119.2083	68.4951	6.900	-0.00753	-.1807	2.979
4500	25.699	104.9690	231.0579	119.7327	66.9693	6.748	-0.00776	-.8418	2.912
4600	25.705	107.5392	233.6281	120.3476	65.5101	6.602	-0.00806	-1.4740	2.849
4700	25.710	110.1099	236.1988	120.9005	64.1135	6.461	-0.00784	-2.0703	2.788
4800	25.716	112.6812	238.7701	121.4418	62.7733	6.328	-0.00823	-2.6894	2.730
4900	25.720	116.2330	241.3419	121.4721	61.4921	6.198	-0.00800	-3.2168	2.673
5000	25.725	117.8258	243.9142	122.4918	60.2605	6.075	-0.00818	-3.7499	2.619
5100	25.729	120.3980	246.4869	123.0013	59.0775	5.956	-0.00828	-4.2630	2.568
5200	25.733	122.9711	249.0600	123.5009	57.9404	5.842	-0.00836	-4.7564	2.518
5300	25.737	125.5446	251.6335	123.9911	56.8465	5.731	-0.00820	-5.3812	2.470
5400	25.741	128.1185	254.2074	124.4722	55.7934	5.625	-0.00823	-5.8884	2.424
5500	25.746	130.6928	256.7817	124.9446	54.7789	5.524	-0.00843	-6.1290	2.379
5600	25.748	128.2674	259.8563	125.4085	53.8009	5.428	-0.00800	-6.6538	2.337
5700	25.752	126.8424	261.9313	125.8643	52.8575	5.327	-0.00785	-6.9037	2.295
5800	25.756	128.4178	264.5067	126.8122	51.9469	5.235	-0.00769	-7.3695	2.255
5900	25.760	140.9036	267.0825	126.7525	51.0675	5.148	-0.00810	-7.7419	2.216
6000	25.763	142.5698	269.6887	127.1855	50.2176	-----	-----	-8.1115	-----

TABLE XIX—THERMODYNAMIC PROPERTIES OF B_2O_3 (CRYSTAL)

[Molecular weight, 69.64]

T (°K)	C_p^o (cal/mole °K)	$H_T^o - H_0^o$ (kcal/mole)	H_T^o (kcal/mole)	S_T^o (cal/mole °K)	$\frac{\Delta H^o}{RT}$	$\log K$
0		0	48.6839			
298.16	14.73	2.2410	50.9249	13.07	1137.338	456.554
300	14.79	2.2680	50.9519	13.16	1130.890	452.523
400	18.40	3.9240	52.6070	17.90	848.915	329.717
500	21.12	5.9080	54.5919	22.81	679.678	255.968
600	23.26	8.1300	56.8139	26.36	566.642	206.747
700	25.15	10.6520	59.2859	30.09	486.763	171.589
723.16	25.57	11.1400	59.8239	30.91	470.191	164.833

TABLE XX—THERMODYNAMIC PROPERTIES OF B_2O_3 (LIQUID)
[Molecular weight, 69.64]

T (°K)	C_p^o (cal/mole °K)	$H_T^o - H_0^o$ (kcal/mole)	H_T^o (kcal/mole)	S_T^o (cal/mole °K)	$\frac{\Delta H^o}{RT}$	$\delta \left(-\frac{\Delta H^o}{RT} \right) = -\frac{\delta T}{100} \left(\frac{a}{T} + b \right)$	$\log K'$	$\delta \log K = -\frac{\delta T}{100} \left(\frac{c}{T} + d \right)$	
						a		c	
723.16 800 900 1000	31.75 31.660 31.242 30.835	16.5600 18.9962 22.1413 25.2452	65.2439 67.6801 70.8252 73.9291	38.41 41.6117 45.3166 48.5872	466.420 421.294 374.121 336.4027	----- ----- ----- 34.014	164.833 145.384 125.064 108.8151	----- ----- ----- 14.870	
	30.680 30.442 30.392 30.377 30.372	28.3159 31.3670 34.4057 37.4472 40.4546	76.9998 80.0509 83.0926 86.1311 89.1685	51.5141 54.1690 56.6037 58.8554 60.9511	206.5560 229.8882 258.1172 289.4828 228.3331	30.893 28.281 26.085 24.226 22.610	-0.04637 -0.02131 -0.04589 -0.00097 -0.00015	95.5391 84.4852 75.1397 67.1358 60.2049	-0.05693 -0.5142 -0.4881 -0.4377 -0.4040
	30.370 30.370 30.370 30.370 30.370	43.5217 46.5587 49.5957 52.6327 55.6697	92.2056 95.2426 98.2798 101.3166 104.3536	62.9112 64.7523 66.4982 68.1308 69.8680	209.2020 196.7334 185.6500 175.7334 166.8082	21.197 19.951 18.861 17.851 16.938	-0.00022 -0.00449 -0.0024 -0.00030 -0.00024	54.1453 48.8090 44.8083 39.8165 36.0020	-0.03770 -0.3686 -0.3346 -0.3150 -0.2890
	30.370 30.370 30.370 30.370 30.370	58.7087 61.7437 64.7807 67.8177 70.8547	107.3906 110.4276 113.4646 116.5016 119.5386	71.1698 72.5226 73.9326 75.2251 76.4649	158.7322 151.3922 144.8597 138.5468 132.8635	16.151 15.416 14.746 14.131 13.449	-0.00036 -0.0011 -0.0027 -0.0010 -----	32.5588 29.4915 26.5641 23.9469 21.3411	6.954 6.835 6.344 6.077 -----
2100 2200 2300 2400 2500	30.270 30.370 30.370 30.370 30.370	58.7087 61.7437 64.7807 67.8177 70.8547	107.3906 110.4276 113.4646 116.5016 119.5386	71.1698 72.5226 73.9326 75.2251 76.4649	158.7322 151.3922 144.8597 138.5468 132.8635	16.151 15.416 14.746 14.131 13.449	-0.00036 -0.0011 -0.0027 -0.0010 -----	32.5588 29.4915 26.5641 23.9469 21.3411	-0.02961 -0.22738 -0.2613 -0.2800 -----

* Enthalpy change in converting B_2O_3 (crystal) at 0° K to B_2O_3 (liquid) at temperature indicated.

TABLE XXI—THERMODYNAMIC PROPERTIES OF C (GAS)
[Atomic weight, 12.010]

T (°K)	C_p^o (cal/mole °K)	$H_T^o - H_0^o$ (kcal/mole)	H_T^o (kcal/mole)	S_T^o (cal/mole °K)
0 298.16 300 400 500	----- 4.9808 4.9801 4.9747 4.9728	0 1.5689 1.5681 2.0858 2.5631	262.3181 263.8770 263.8862 264.8839 264.8812	----- 27.7611 37.7917 38.2235 40.3333
	600	4.9709	8.0603	41.2398
	700	4.9701	3.5573	42.0060
	800	4.9697	4.0543	42.6896
	900	4.9693	4.5513	43.2560
1000	4.9691	5.0482	287.3663	43.7785
1100 1200 1300 1400 1500	4.9691 4.9697 4.9705 4.9725 4.9747	5.5451 6.0421 6.5301 7.0382 7.5363	287.8632 288.3602 288.8572 289.3543 289.8517	44.2621 44.6845 45.0823 45.4507 45.7893
	1600	4.9783	8.0312	46.1160
	1700	4.9835	8.5293	46.4170
	1800	4.9899	9.2280	46.7020
	1900	4.9980	9.5274	46.9720
2000	5.0075	10.0277	272.3458	47.2237
2100 2200 2300 2400 2500	5.0189 5.0316 5.0455 5.0607 5.0769	10.8290 11.0315 11.6354 12.0407 12.5476	272.8471 273.3496 273.8535 274.3588 274.8557	47.4732 47.7070 47.9310 48.1480 48.3530
	2600	5.0941	13.0561	49.5524
	2700	5.1118	13.5664	49.7450
	2800	5.1299	14.0785	49.9312
	2900	5.1486	14.5924	49.1116
3000	5.1677	15.1082	277.4268	49.2964
3100 3200 3300 3400 3500	5.1866 5.2055 5.2243 5.2428 5.2610	15.6259 16.1455 16.8670 17.1904 17.7188	275.3742 275.8845 276.3966 276.9105 280.0837	49.4552 49.6212 49.7818 49.9370 50.0901
	3600	5.2786	18.2426	50.2836
	3700	5.2959	18.7713	50.3834
	3800	5.3126	19.3017	50.5249
	3900	5.3286	19.8338	50.6631
4000	5.3442	20.3674	282.6856	50.7932
4100 4200 4300 4400 4500	5.3690 5.3732 5.3886 5.3994 5.4116	20.9026 21.4392 21.9772 22.5165 23.0570	283.2207 283.7673 284.2953 284.8347 285.3571	50.9303 51.0598 51.1862 51.3102 51.4317
	4600	5.4227	23.9587	51.5508
	4700	5.4331	24.1415	51.6375
	4800	5.4427	24.6553	51.7820
	4900	5.4514	25.2300	51.8943
5000	5.4592	25.7755	288.0936	52.0045
5100 5200 5300 5400 5500	5.4661 5.4720 5.4770 5.4810 5.4841	26.3218 26.8387 27.4162 27.9841 28.5123	288.6399 289.1868 289.7343 290.2822 290.8304	52.1127 52.2199 52.3231 52.4256 52.5232
	5600	5.4865	29.0608	52.6250
	5700	5.4882	29.6086	52.7221
	5800	5.4893	30.1686	52.8176
	5900	5.4898	30.7074	52.9114
6000	5.4899	31.2684	283.5745	52.0037

TABLE XXII—THERMODYNAMIC PROPERTIES OF CO (GAS)

[Molecular weight, 28.010]

T (°K)	C_p (cal/mole °K)	$H_r^{\circ} - H_o^{\circ}$ (kcal/mole)	H_r° (kcal/mole)	S_r° (cal/mole °K)	$\frac{-\Delta H^{\circ}}{RT}$	$\delta \left(-\frac{\Delta H^{\circ}}{RT} \right) = \frac{-\delta T}{100} \left(\frac{a}{T} + b \right)$	log K	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c}{T} + d \right)$	
								c	d
0	6.965	0	65.7461	65.7461	434.2122	152.5536			
298.16	6.965	2.0727	67.8188	47.301	431.5591	181.0967			
300	6.965	2.0845	67.8316	47.342	431.5591	181.0967			
400	7.013	2.7838	68.5209	49.352	324.0685	134.2147			
500	7.120	3.4900	69.2381	50.927	269.5584	106.0510			
600	7.276	4.2085	69.9556	52.238	216.5368	87.2636			
700	7.451	4.9458	70.6919	53.373	185.7031	73.8126			
800	7.624	5.6998	71.4459	54.379	162.7232	63.7218			
900	7.787	6.4706	72.2167	55.287	144.7699	55.8633			
1000	7.932	7.2565	73.0028	56.1160	130.3992	49.5787	5840	0.02293	
1100	8.058	8.0580	73.8021	56.8779	118.6348	44.4266	5131	0.01927	
1200	8.187	8.8673	74.6184	57.5837	108.8261	40.1814	4706	.01680	
1300	8.265	9.6889	75.4350	58.2413	100.5223	36.4946	4346	.01491	
1400	8.349	10.5196	76.2687	58.8569	98.4014	33.3754	4038	.01310	
1500	8.419	11.3580	77.1041	59.4353	87.2274	30.6703	3771	.01142	
1600	8.481	12.2030	77.9491	59.0806	81.8231	28.3020	3587	0.01081	
1700	8.536	13.0538	78.7999	60.4664	77.0530	26.2111	3330	.00960	
1800	8.586	13.9098	79.6580	60.8857	72.8115	24.3815	3146	.00889	
1900	8.627	14.7705	80.5166	61.4610	68.0168	22.6868	2982	.00800	
2000	8.665	15.6361	81.3812	61.8845	65.5983	21.1878	2834	.00748	
2100	8.699	16.5033	82.2494	62.8181	62.5060	19.8308	2700	0.00693	
2200	8.730	17.3747	83.1208	62.7234	59.6043	18.5906	2578	.00653	
2300	8.758	18.2491	83.9952	63.1121	57.1267	17.4802	2467	.00608	
2400	8.784	19.1262	84.3723	63.4864	54.7729	16.4352	2366	.00580	
2500	8.806	20.0067	85.7618	63.8444	52.6073	15.4854	2271	.00544	
2600	8.827	20.8874	86.6385	64.1902	50.6082	14.6045	2184	0.00531	
2700	8.847	21.7711	87.5172	64.5238	48.7572	13.7903	2104	.00507	
2800	8.865	22.6567	88.4028	64.8458	47.0384	13.0388	2029	.00494	
2900	8.882	23.5440	89.2901	65.1672	45.4583	12.3292	1959	.00490	
3000	8.898	24.4330	90.1791	65.4686	43.9460	11.6713	1894	.00483	
3100	8.913	25.3246	91.0707	65.7606	42.5480	11.0555	1834	0.00448	
3200	8.927	26.2168	91.9627	66.0388	41.2387	10.4779	1777	.00432	
3300	8.939	27.1099	92.8580	66.3087	40.0089	9.9351	1723	.00444	
3400	8.952	28.0044	93.7505	66.5757	38.8517	9.4239	1673	.00420	
3500	8.963	28.9902	94.6463	66.8854	37.7607	8.9417	1626	.00403	
3600	8.974	29.7970	95.5481	67.0890	36.7307	8.4960	1580	0.00417	
3700	8.985	30.6940	96.4411	67.3340	35.7565	8.0518	1538	.00406	
3800	8.996	31.5940	97.3401	67.5738	34.8238	7.6460	1493	.00390	
3900	9.005	32.4940	98.2401	67.8076	33.9586	7.2590	1400	.00380	
4000	9.015	33.3880	99.1411	68.0357	33.1274	6.8892	1423	.00388	
4100	9.024	34.2969	100.0430	68.2884	32.3370	6.5382	1389	0.00379	
4200	9.034	35.1998	100.9459	68.4760	31.5844	6.2037	1356	.00355	
4300	9.042	36.1038	101.8497	68.8887	30.8670	5.8847	1325	.00368	
4400	9.051	37.0083	102.7544	68.9566	30.1823	5.5799	1295	.00362	
4500	9.059	37.9188	103.6599	69.1001	29.5283	5.2885	1266	.00358	
4600	9.067	38.8201	104.5662	69.2993	28.9029	5.0097	1239	0.00358	
4700	9.074	39.7271	105.4732	69.4944	28.3043	4.7425	1213	.00349	
4800	9.082	40.6349	106.3810	69.6855	27.7008	4.4933	1187	.00346	
4900	9.089	41.5436	107.2896	69.8728	27.1808	4.2405	1164	.00340	
5000	9.096	42.4527	108.1988	70.0585	26.6529	4.0043	1140	.00347	
5100	9.103	43.3627	109.1088	70.2367	26.1459	3.7773	1118	0.00340	
5200	9.110	44.2733	110.0194	70.4136	25.6585	3.5689	1097	.00332	
5300	9.117	45.1847	110.9308	70.5872	25.1896	3.3456	1077	.00326	
5400	9.123	46.0967	111.8428	70.7676	24.7351	3.1489	1057	.00322	
5500	9.130	47.0098	112.7554	70.9261	24.3032	2.988	1037	.00332	
5600	9.137	47.9227	113.6688	71.0897	23.8838	2.8116	1019	0.00333	
5700	9.143	48.8367	114.5828	71.2514	23.4702	2.6799	1001	.00321	
5800	9.150	49.7513	115.4974	71.4105	23.0887	2.5284	984	.00322	
5900	9.156	50.6666	116.4127	71.5670	22.7114	2.4241	968	.00317	
6000	9.162	51.5825	117.3286	71.7209	22.3467	2.3090	—	—	

TABLE XXIII—THERMODYNAMIC PROPERTIES OF CO₂ (GAS)

[Molecular weight, 44.010]

T (°K)	C _s (cal mole °K)	H _f —H ₉ (kcal) mole	H _f (kcal) mole	S _f (cal mole °K)	—ΔH° RT	δ($\frac{\Delta H}{R T}$) = $\frac{-\delta T}{100} \left(\frac{a}{T} + b \right)$		log K	δ log K = $\frac{-\delta T}{100} \left(\frac{c}{T} + d \right)$	
						a	b		c	d
0		0	0	51.061	648.2084					
298.16	8.874	2.2381	2.2381	51.116	644.2627			267.6053		
300	8.894	2.2546	2.2546	51.116	644.2627			265.8787		
400	9.871	3.1945	3.1945	53.815	483.6369			195.8795		
500	10.662	4.2228	4.2228	56.113	287.5422			153.8214		
600	11.311	5.3224	5.3224	58.109	323.3792			125.7489		
700	11.849	6.4513	6.4513	59.895	277.4307			105.6751		
800	12.300	7.6894	7.6894	61.507	242.9362			90.6086		
900	12.673	8.9399	8.9399	62.980	216.0824			78.8821		
1000	12.995	10.2220	10.2220	64.3310	194.5323	10.258	0.07095	69.4963	8428	0.02238
1100	13.265	11.5350	11.5350	66.5822	176.9768	17.548	0.05867	61.8111	7866	0.01797
1200	13.490	12.8728	12.8728	68.7461	162.2948	18.097	0.04919	55.4048	7031	-0.01434
1300	13.680	14.2312	14.2312	67.8334	149.5833	14.388	0.04210	49.0520	6194	-0.01103
1400	13.844	15.6074	15.6074	68.8582	139.2012	18.814	0.03647	45.3324	6033	-0.00880
1500	13.988	16.9990	16.9990	69.8132	129.9554	12.900	0.03180	41.3016	5633	-0.00718
1600	14.116	18.4042	18.4042	70.7200	121.3611	12.100	0.02796	37.7788	5283	0.00585
1700	14.230	19.6216	19.6216	71.5792	114.7155	11.395	0.02394	34.8603	4974	-0.00457
1800	14.331	21.2496	21.2496	72.3955	108.3810	10.767	0.02116	31.8923	4699	-0.00344
1900	14.421	22.6872	22.6872	73.1727	102.6780	10.206	0.01820	29.4162	4453	-0.00320
2000	14.502	24.1334	24.1334	73.9145	97.5618	9.701	0.01648	27.1855	4221	-0.00274
2100	14.576	25.5872	25.5872	74.6228	92.9165	9.244	0.01318	25.1680	4030	0.00248
2200	14.643	27.0482	27.0482	75.3084	88.7015	8.828	0.01124	23.3337	3848	-0.00196
2300	14.705	28.5156	28.5156	75.9557	84.5523	8.447	0.01002	21.6587	3881	-0.00175
2400	14.763	29.9890	29.9890	76.5828	81.8227	8.099	0.00850	20.1232	3529	-0.00120
2500	14.817	31.4680	31.4680	77.1865	78.0485	7.778	0.00716	18.7104	3383	-0.00112
2600	14.863	32.9522	32.9522	77.7887	76.8759	7.482	0.00599	17.4062	3268	0.00093
2700	14.916	34.4414	34.4414	78.3307	72.2688	7.208	0.00491	16.1856	3133	-0.00069
2800	14.961	35.9863	35.9863	78.8740	69.7198	6.955	0.00322	15.0772	3026	-0.00066
2900	15.003	37.4335	37.4335	79.3997	67.3181	6.717	0.00260	14.0381	2922	-0.00060
3000	15.043	38.9358	38.9358	79.9080	65.0765	6.496	0.00172	13.0555	2825	-0.00041
3100	15.081	40.4420	40.4420	80.4029	62.9793	6.289	0.00079	12.1468	2734	0.00032
3200	15.117	41.9519	41.9519	80.8822	61.0132	6.094	-0.00048	11.2921	2649	-0.00027
3300	15.152	43.4654	43.4654	81.3480	59.1661	5.912	-0.00052	10.4891	2663	-0.00051
3400	15.185	44.9822	44.9822	81.8008	57.4273	5.740	-0.00100	9.7333	2493	-0.00081
3500	15.216	46.5022	46.5022	82.2414	55.7858	5.573	-0.01154	9.0207	2421	-0.00050
3600	15.246	48.0254	48.0254	82.6705	54.2409	5.424	-0.01684	8.3477	2354	0.00048
3700	15.275	49.5514	49.5514	83.0886	52.7768	5.280	-0.02267	7.7110	2280	-0.00047
3800	15.302	51.0802	51.0802	83.4963	51.3899	5.141	-0.02250	7.1079	2230	-0.00051
3900	15.329	52.6118	52.6118	83.8941	50.0742	5.011	-0.02295	6.5963	2173	-0.00045
4000	15.355	54.1480	54.1480	84.2826	48.8244	4.886	-0.03111	5.9919	2119	-0.00037
4100	15.380	55.6826	55.6826	84.6820	47.5368	4.767	-0.00310	5.4747	2061	0.00046
4200	15.405	57.2220	57.2220	85.0629	46.0839	4.654	-0.00322	4.9821	2018	-0.00040
4300	15.429	58.7637	58.7637	85.3957	45.4218	4.545	-0.00318	4.5124	1970	-0.00057
4400	15.452	60.3073	60.3073	85.7507	44.3915	4.443	-0.00333	4.0641	1926	-0.00060
4500	15.475	61.8541	61.8541	86.0982	43.4108	4.343	-0.00313	3.6356	1883	-0.00055
4600	15.496	63.4026	63.4026	86.4386	42.4696	4.249	-0.00314	3.2257	1842	0.00049
4700	15.520	64.9336	64.9336	86.7721	41.5683	4.138	-0.0305	2.8333	1803	-0.00048
4800	15.542	66.5068	66.5068	87.0991	40.7057	4.070	-0.0271	2.4572	1785	-0.00060
4900	15.564	68.0620	68.0620	87.4198	39.8778	3.986	-0.0260	2.0864	1729	-0.00068
5000	15.586	69.6196	69.6196	87.7344	39.0831	3.905	-0.0229	1.7500	1694	-0.00064
5100	15.603	71.1792	71.1792	88.0433	38.3198	3.827	-0.00196	1.4172	1661	0.00068
5200	15.620	72.7412	72.7412	88.2466	37.5558	3.752	-0.0172	1.0971	1629	-0.00064
5300	15.632	74.3032	74.3032	88.4445	36.8798	3.680	-0.0153	.7891	1598	-0.00067
5400	15.674	75.8716	75.8716	88.8873	36.1987	3.610	-0.0116	.4925	1568	-0.00071
5500	15.696	77.4400	77.4400	89.2251	35.5445	3.543	-0.00888	.2067	1540	-0.00070
5600	15.718	79.0108	79.0108	89.5081	34.9127	3.478	-0.00068	-0.0690	1512	0.00074
5700	15.740	80.5836	80.5836	89.7845	34.3032	3.416	-0.00087	-0.3850	1456	-0.00069
5800	15.762	82.1588	82.1588	90.0804	33.7146	3.356	-0.00081	-0.5919	1460	-0.00074
5900	15.784	83.7360	83.7360	90.3301	33.1461	3.298	-0.00007	-0.8401	1435	-0.00073
6000	15.806	85.3156	85.3156	90.5935	32.5968	-----	-1.0500	-----	-----	-----

TABLE XXIV—THERMODYNAMIC PROPERTIES OF
Cl (GAS)

[Atomic weight, 33.457]

T (°K)	C_p^o ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)	$H_F^o - H_O^o$ (kcal/mole)	H_F^o (kcal/mole)	S_F^o ($\frac{\text{cal}}{\text{mole} \cdot \text{°K}}$)
0 296.16	5.2203	0	32.5131	
	5.2237	1.4991	34.0132	39.4569
	5.2271	1.5057	34.0218	39.4890
	5.3705	2.0391	34.5522	41.0138
	5.4968	2.5901	35.0932	42.2206
600 700 800 900 1000	5.4448	3.1244	35.6376	43.2132
	5.4232	3.6880	36.1811	44.0511
	5.3887	4.2088	36.7217	44.7731
	5.3606	4.7458	37.2887	45.4086
	5.3133	5.2788	37.7919	45.9674
1100 1200 1300 1400 1500	5.2788	5.8084	38.3215	46.4722
	5.2477	6.3347	38.8478	46.9302
	5.2201	6.8581	39.3712	47.3491
	5.1958	7.3739	39.8920	47.7351
	5.1745	7.8974	40.4105	48.0928
1600 1700 1800 1900 2000	5.1557	8.4189	40.9270	48.4282
	5.1892	8.9286	41.4417	48.7383
	5.1246	9.4418	41.9538	49.0316
	5.1117	9.9536	42.4667	49.3083
	.1002	10.4642	42.9773	49.5702
2100 2200 2300 2400 2500	5.0900	10.9737	43.4988	49.8188
	5.0809	11.4828	43.9954	50.0554
	5.0737	11.9900	44.5031	50.2811
	5.0654	12.4989	45.0100	50.4958
	5.0588	13.0081	45.6182	50.7084
2600 2700 2800 2900 3000	5.0528	13.5087	46.0218	50.9017
	5.0474	14.0127	46.5268	51.0923
	5.0425	14.5182	47.0313	51.2758
	5.0380	15.0222	47.5353	51.4527
	5.0339	15.5258	48.0399	51.6224
3100 3200 3300 3400 3500	5.0301	16.0200	48.5421	51.7884
	5.0267	16.5318	49.0449	51.9490
	5.0235	17.0343	49.5474	52.1027
	5.0206	17.5365	50.0496	52.2526
	5.0179	18.0385	50.5516	52.3981
3600 3700 3800 3900 4000	5.0154	18.5401	51.0532	52.5994
	5.0131	19.0416	51.5547	52.6768
	5.0109	19.5428	52.0564	52.8103
	5.0089	20.0437	52.5588	52.9406
	5.0070	20.5445	53.0576	53.0674
4100 4200 4300 4400 4500	5.0052	21.0452	53.5583	53.1910
	5.0035	21.5458	54.0587	53.3116
	5.0020	22.0459	54.5590	53.4298
	5.0006	22.5460	55.0591	53.5443
	4.9983	23.0460	55.5591	53.6566
4600 4700 4800 4900 5000	4.9981	23.5459	56.0590	53.7666
	4.9970	24.0456	56.5587	53.8740
	4.9960	24.5453	57.0584	53.9792
	4.9950	25.0448	57.5579	54.0822
	4.9941	25.5443	58.0574	54.1831
5100 5200 5300 5400 5500	4.9932	26.0436	58.5567	54.2820
	4.9924	26.5429	59.0560	54.3759
	4.9916	27.0421	59.5552	54.4740
	4.9908	27.5412	60.0543	54.5673
	4.9901	28.0403	60.5534	54.6589
5600 5700 5800 5900 6000	4.9894	28.5393	61.0524	54.7488
	4.9887	29.0382	61.5513	54.8371
	4.9880	29.5370	62.0501	54.9239
	4.9873	30.0368	62.5489	55.0091
	4.9866	30.5345	63.0476	55.0929

TABLE XXV—THERMODYNAMIC PROPERTIES OF Cl₂ (GAS)

[Molecular weight, 70.914]

T (°K)	C _p (cal/mole °K)	H _r ^o - H ₀ ^o (cal/mole)	H _r ^o (cal/mole)	S _r ^o (cal/mole °K)	$\frac{\Delta H^o}{RT}$	$\delta \left(\frac{\Delta H^o}{RT} \right) = \frac{-\delta T}{100} \left(\frac{a}{T} + b \right)$	log K	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c}{T} + d \right)$	
								c	d
0		0	7.8081						
298.16	8.11	2.1939	10.0000	53.286	97.9319			36.9304	
300	8.12	2.2089	10.0150	53.336	97.9383			36.8695	
400	8.44	3.0384	10.8445	55.720	73.2947			26.0820	
500	8.62	3.8920	11.6981	57.625	58.8656			19.7044	
600	8.74	4.7610	12.5871	59.207	49.2389			15.4354	
700	8.82	5.6399	13.4480	60.562	42.3545			12.3755	
800	8.88	6.5248	14.3809	61.744	37.1837			10.0725	
900	8.92	7.4142	15.2203	62.792	33.1554			8.2757	
1000	8.96	8.3090	16.1151	63.7360	29.9262	2834	0.02478	6.8337	1282 0.01765
1100	8.99	9.2085	17.0126	64.5904	27.2796	2824	0.02283	5.6606	1168 0.01517
1200	9.02	10.1070	17.9131	65.3739	25.0701	2410	0.01895	4.6621	1073 0.01312
1300	9.04	11.0100	18.8161	66.0967	23.1973	2227	0.01719	3.8236	992 0.01153
1400	9.06	11.9150	19.7211	66.7674	21.5894	2070	0.01570	3.1032	923 0.01047
1500	9.08	12.8220	20.6281	67.3931	20.1937	1980	0.01485	2.4774	863 0.00923
1600	9.109	13.7315	21.5376	67.9800	18.9705	1817	0.01228	1.9288	810 0.00863
1700	9.124	14.6481	22.4492	68.5327	17.8894	1712	0.0109	1.4457	764 0.00786
1800	9.139	15.5663	23.3624	69.0547	16.9272	1618	0.01042	1.0116	722 0.00720
1900	9.155	16.4709	24.2770	69.5492	16.0652	1534	0.00900	0.6244	686 0.00620
2000	9.171	17.3873	25.1934	70.0192	15.2883	1480	0.00856	0.2752	653 0.00545
2100	9.185	18.3051	26.1112	70.4570	14.5845	1391	0.00623	-0.0412	623 0.00492
2200	9.200	19.2243	27.0304	70.8946	13.9440	1329	0.00757	-0.3293	595 0.00450
2300	9.215	20.1451	27.9512	71.3039	13.3685	1272	0.00740	-0.5928	570 0.00440
2400	9.230	21.0673	28.8734	71.6964	12.8211	1220	0.00700	-0.8347	547 0.00410
2500	9.244	21.9910	29.7971	72.0735	12.3261	1172	0.00663	-1.0576	526 0.00379
2600	9.259	22.9161	30.7222	72.4364	11.8687	1128	0.00632	-1.2637	506 0.00359
2700	9.273	23.8427	31.6188	72.7860	11.4446	1067	0.00569	-1.4547	488 0.00331
2800	9.287	24.7707	32.5768	73.1236	11.0504	1049	0.00568	-1.6328	471 0.00319
2900	9.300	25.7001	33.5062	73.4497	10.6830	1012	0.00597	-1.7979	456 0.00290
3000	9.315	26.6309	34.4370	73.7662	10.3397	981	0.00496	-1.9527	441 0.00264
3100	9.327	27.5629	35.3690	74.0708	10.0188	949	0.00514	-2.0978	427 0.00256
3200	9.341	28.4963	36.3024	74.2672	9.7186	919	0.00532	-2.2236	415 0.00224
3300	9.355	29.4311	37.2372	74.5518	9.4328	883	0.00465	-2.3616	402 0.00226
3400	9.368	30.3673	38.1734	74.8348	9.1655	856	0.00457	-2.4921	391 0.00209
3500	9.382	31.3048	39.1109	75.2060	8.9132	843	0.00443	-2.6559	381 0.00177
3600	9.395	32.2437	40.0498	75.4706	8.6746	819	0.00455	-2.7035	371 0.00163
3700	9.409	33.1839	40.9900	76.7281	8.4487	798	0.00430	-2.8054	361 0.00160
3800	9.422	34.1254	41.9315	76.9792	8.2244	778	0.00453	-2.9020	352 0.00144
3900	9.436	35.0683	42.8744	78.2241	8.0309	758	0.00410	-2.9987	343 0.00155
4000	9.448	36.0125	43.8186	78.4632	7.8373	739	0.00406	-3.0810	334 0.00154
4100	9.461	36.9579	44.7640	78.6966	7.6530	721	0.00403	-3.1640	327 0.00134
4200	9.474	37.9047	45.7108	78.9248	7.4773	708	0.00481	-3.2432	319 0.00131
4300	9.488	38.8528	46.6559	77.1479	7.3095	688	0.00394	-3.3187	312 0.00129
4400	9.501	39.8023	47.6084	77.3862	7.1492	672	0.00397	-3.3909	305 0.00122
4500	9.514	40.7330	48.5591	77.6798	6.9969	658	0.00386	-3.4699	299 0.00110
4600	9.527	41.7051	49.5112	77.8791	6.8490	644	0.00378	-3.5260	292 0.00117
4700	9.540	42.6584	50.4645	77.9941	6.7082	630	0.00385	-3.5933	286 0.00112
4800	9.553	43.6131	51.4192	78.1951	6.5731	617	0.00378	-3.6500	281 0.00095
4900	9.566	44.5680	52.3751	78.3922	6.4434	605	0.00370	-3.7083	275 0.00100
5000	9.579	45.5283	53.3324	78.5856	6.3187	593	0.00363	-3.7643	270 0.00086
5100	9.592	46.4868	54.2909	78.7754	6.1988	581	0.00377	-3.8181	265 0.00084
5200	9.606	47.4447	55.2508	78.9618	6.0833	569	0.00384	-3.8869	260 0.00084
5300	9.619	48.4069	56.2120	79.1449	5.9721	559	0.00378	-3.9198	255 0.00078
5400	9.632	49.3684	57.1745	79.3248	5.8648	549	0.00388	-3.9678	250 0.00085
5500	9.645	50.3233	58.1384	79.5016	5.7613	539	0.00365	-4.0141	246 0.00077
5600	9.658	51.2974	59.1035	79.6765	5.6614	530	0.00362	-4.0588	242 0.00074
5700	9.671	52.2639	60.0700	79.8466	5.5648	520	0.00384	-4.1020	238 0.00087
5800	9.684	53.2316	61.0377	80.0149	5.4715	511	0.00369	-4.1457	233 0.00071
5900	9.697	54.2007	62.0068	80.1806	5.3812	503	0.00357	-4.1839	230 0.00067
6000	9.710	55.1660	62.9771	80.3436	5.2933	-----	-----	-4.2229	-----

TABLE XXVI—THERMODYNAMIC PROPERTIES OF CIF (GAS)

[Molecular weight, 54.457]

T (°K)	C_p^o (cal/mole °K)	$H_r^o - H_o^o$ (kcal/mole)	H_r^o (kcal/mole)	S_r^o (cal/mole °K)	$\frac{\Delta H^o}{RT}$	$s \left(\frac{\Delta H^o}{RT} \right) - \frac{d}{100} \left(\frac{c}{T} + b \right)$	$\log K$	$s \log K = \frac{-sT}{100} \left(\frac{c}{T} + d \right)$	
								c	d
0	7.6517	0	21.2069	52.0438	102.1326	38.8196			
298.16	7.6517	2.1281	23.8350	52.0904	101.5154	38.5476			
300	7.6599	2.1422	23.3491	52.0904	101.5154	38.5476			
400	8.0382	2.2933	24.1851	54.3491	76.4945	27.5018			
500	8.2920	3.7456	24.9525	56.1720	61.4528	20.8444			
600	8.4594	4.5839	25.7907	57.8907	51.4044	16.3892			
700	8.5723	5.4857	26.6426	59.0127	44.2125	13.1937			
800	8.6511	6.2971	27.5040	60.1628	38.8061	10.7898			
900	8.7077	7.1662	28.3731	61.1852	34.5972	8.9145			
1000	8.7496	8.0361	29.2450	62.1049	31.2228	7.4100	1337	0.01585	
1100	8.7814	8.9147	30.1216	62.9404	28.4577	6.1757	1218	0.01520	
1200	8.8090	9.7940	31.0009	63.7055	26.1504	5.1445	1110	0.01283	
1300	8.8285	10.6756	31.8825	64.4111	24.1955	4.2699	1033	0.01211	
1400	8.8411	11.5589	32.7658	65.0567	22.5180	3.5185	962	0.01127	
1500	8.8538	12.4437	33.6606	65.6761	21.0266	2.8659	900	0.00980	
1600	8.8644	13.3296	34.5365	66.2479	19.7879	2.2936	845	0.00904	
1700	8.8732	14.2155	35.4234	66.7855	18.6622	1.7875	796	0.00848	
1800	8.8808	15.1042	36.3111	67.2929	17.6608	1.3368	753	0.00778	
1900	8.8875	15.9928	37.1995	67.7733	16.7641	1.0327	714	0.00730	
2000	8.8937	16.8817	38.0868	68.2298	15.9566	.5684	680	0.00649	
2100	8.8997	17.7713	38.9782	68.6634	15.2255	0.2381	618	0.00635	
2200	8.9059	18.6616	39.8685	69.0775	14.5604	0.0412	619	0.00607	
2300	8.9128	19.5525	40.7504	69.4736	13.9528	0.0448	593	0.00562	
2400	8.9202	20.4442	41.6511	69.8530	13.3954	0.0430	569	0.00530	
2500	8.9291	21.3386	42.5435	70.2174	12.8223	0.0477	547	0.00492	
2600	8.9398	22.2301	43.4370	70.5678	11.73	0.0476	527	0.00461	
2700	8.9525	23.1247	44.3316	70.9054	11.9601	-1.0389	508	0.00427	
2800	8.9678	24.0207	45.2276	71.2313	11.5909	-1.2387	490	0.00433	
2900	8.9858	24.9184	46.1253	71.5463	11.1804	-1.4245	460	0.00390	
3000	9.0072	25.8180	47.0249	71.8513	10.8249	-1.5978	439	0.00374	
3100	9.0320	26.7200	47.9260	72.1470	10.4918	-1.7646	415	0.00344	
3200	9.0506	27.6246	48.8315	72.4242	10.1791	-2.0540	402	0.00319	
3300	9.0632	28.5323	49.7392	72.7135	9.8848	-2.1881	419	0.00306	
3400	9.1299	29.4435	50.6504	72.9855	9.6073	-2.3144	406	0.00273	
3500	9.1709	30.3585	51.5654	73.2508	9.3450	-2.4337	397	0.00252	
3600	9.2162	31.2779	52.4848	73.5098	9.0966	823	387	0.00221	
3700	9.2658	32.2020	53.4089	73.7630	8.8610	797	377	0.00219	
3800	9.3197	33.1312	54.3381	74.0108	8.6371	772	368	0.00184	
3900	9.3778	34.0661	55.2730	74.2536	8.4288	749	359	0.00175	
4000	9.4399	35.0070	56.2139	74.4918	8.2205	726	351	0.00149	
4100	9.5059	35.9543	57.1612	74.7237	8.0263	705	343	0.00133	
4200	9.5754	36.9084	58.1153	74.9556	7.8404	684	338	0.00106	
4300	9.6485	37.8698	59.0765	75.1818	7.6624	666	329	0.00093	
4400	9.7246	38.8382	60.0451	75.4045	7.4915	647	322	0.00074	
4500	9.8035	39.8146	61.0215	75.6239	7.3274	630	316	0.00050	
4600	9.8849	40.7990	62.0059	75.8403	7.1696	614	310	0.00024	
4700	9.9686	41.7917	62.9985	76.0598	7.0175	599	305	0.00004	
4800	10.0539	42.7928	63.9997	76.2845	6.8709	585	299	0.00012	
4900	10.1407	43.8026	65.0095	76.4727	6.7293	572	294	0.00030	
5000	10.2287	44.8210	66.0279	76.6785	6.5926	560	289	0.00087	
5100	10.3173	45.8483	67.0552	76.8919	6.4603	548	284	-0.00072	
5200	10.4064	46.8845	68.0914	77.0631	6.3322	538	280	-0.00063	
5300	10.4955	47.9206	69.1385	77.2822	6.2081	528	275	-0.00103	
5400	10.5844	48.9536	70.1905	77.4792	6.0678	519	270	-0.00109	
5500	10.6726	50.0465	71.2584	77.6742	5.9710	511	267	-0.00138	
5600	10.7597	51.1181	72.3250	77.8673	5.8576	504	263	-0.00154	
5700	10.8457	52.1983	73.4052	78.0885	5.7474	497	259	-0.00166	
5800	10.9302	53.2871	74.4940	78.2478	5.6403	491	255	-0.00182	
5900	11.0129	54.3843	75.5912	78.4354	5.5361	485	252	-0.00190	
6000	11.0937	55.4896	76.6965	78.6212	5.4346	478	248	-0.00193	

TABLE XXVII—THERMODYNAMIC PROPERTIES OF F (GAS)

[Molecular weight, 19.00]

T (°K)	C_p^o (cal mole °K)	$H_f^o - H_g^o$ (kcal mole)	H_f^o (kcal mole)	S_f^o (cal mole °K)
0		0	48.2731	
298.16	5.4384	1.5580	49.8361	37.9173
300	5.4355	1.5620	49.8461	37.9507
400	5.3612	2.1081	50.3862	39.5080
500	5.2819	2.6401	50.9182	40.6926
600	5.2179	3.1650	51.4431	41.6497
700	5.1892	3.6842	51.9623	42.4502
800	5.1324	4.1992	52.4773	43.1874
900	5.1043	4.7110	52.9891	43.7407
1000	5.0526	5.2203	53.4984	44.2774
1100	5.0855	5.7277	54.0058	44.7610
1200	5.0519	6.2336	54.5117	45.2012
1300	5.0409	6.7392	55.0163	45.6051
1400	5.0318	7.2419	55.5200	45.9788
1500	5.0244	7.7447	56.0228	46.3282
1600	5.0181	8.2468	56.5249	46.6493
1700	5.0129	8.7483	57.0264	46.9534
1800	5.0084	9.2494	57.5275	47.2998
1900	5.0045	9.7501	58.0282	47.5105
2000	5.0012	10.2508	58.5284	47.7671
2100	4.9983	10.7603	59.0284	48.0110
2200	4.9957	11.2600	59.5281	48.2435
2300	4.9935	11.7485	60.0276	48.4655
2400	4.9915	12.2487	60.5263	48.6780
2500	4.9893	12.7478	61.0259	48.8817
2600	4.9852	13.2467	61.5248	49.0774
2700	4.9808	13.7454	62.0235	49.2656
2800	4.9855	14.2441	62.5222	49.4469
2900	4.9844	14.7425	63.0206	49.6219
3000	4.9834	15.2409	63.5190	49.7908
3100	4.9824	15.7392	64.0173	49.9542
3200	4.9816	16.2374	64.5155	50.1124
3300	4.9808	16.7355	65.0136	50.2667
3400	4.9801	17.2336	65.5117	50.4143
3500	4.9794	17.7316	66.0097	50.5687
3600	4.9788	18.2295	66.5076	50.6990
3700	4.9782	18.7273	67.0054	50.8364
3800	4.9777	19.2251	67.5032	50.9651
3900	4.9772	19.7229	68.0010	51.0974
4000	4.9768	20.2206	68.4987	51.2234
4100	4.9764	20.7182	68.9963	51.3463
4200	4.9760	21.2158	69.4939	51.4662
4300	4.9758	21.7134	69.9915	51.5833
4400	4.9753	22.2110	70.4991	51.6977
4500	4.9750	22.7083	70.9868	51.8095
4600	4.9747	23.2060	71.4841	51.9188
4700	4.9744	23.7034	71.9815	52.0268
4800	4.9741	24.2009	72.4780	52.1305
4900	4.9739	24.6983	72.9754	52.2381
5000	4.9737	25.1956	73.4737	52.3366
5100	4.9735	25.6930	73.9711	52.4320
5200	4.9732	26.1903	74.4684	52.5266
5300	4.9731	26.6876	74.9657	52.6224
5400	4.9729	27.1849	75.4630	52.7163
5500	4.9727	27.6822	75.9608	52.8076
5600	4.9725	28.1795	76.4576	52.8972
5700	4.9724	28.6767	76.9548	52.9852
5800	4.9723	29.1740	77.4521	53.0716
5900	4.9721	29.6712	77.9493	53.1566
6000	4.9720	30.1684	78.4466	53.2402

TABLE XXVIII—THERMODYNAMIC PROPERTIES OF F₂ (GAS)

[Molecular weight, 38.00]

<i>T</i> (°K)	<i>C_o</i> (cal mole °K)	<i>H₂ - H₀</i> (kcal mole)	<i>H_P</i> (kcal mole)	<i>S₀</i> (cal mole °K)	$\frac{\Delta H^o}{RT}$	$\delta \left(\frac{\Delta H^o}{RT} \right) = \frac{-\delta T}{100} \left(\frac{a}{T} + b \right)$	$\log K'$	$\delta \log K' = \frac{-\delta T}{100} \left(\frac{c}{T} + d \right)$	
								<i>a</i>	<i>b</i>
0		0	60.9562						
298.16	7.5183	2.1137	63.0699	48.5590	61.7763			20.8681	
300	7.5262	2.1276	63.0838	48.6033	61.4076			20.7035	
400	7.9077	2.9001	68.8563	60.8261	46.4428			14.0101	
500	8.1822	3.7055	64.9617	62.6211	37.4145			9.9626	
600	8.3704	4.5337	65.4899	54.1806	31.8846			7.2467	
700	8.5004	5.3776	66.9338	55.4313	27.0238			5.2959	
800	8.5924	6.2256	67.1587	56.5727	23.7560			3.8255	
900	8.6593	7.0953	68.0615	57.5888	21.2068			2.6768	
1000	8.7092	7.9648	68.9205	58.5042	19.1610	1825	0.01791	1.7540	817
1100	8.7472	8.8371	69.7938	59.3360	17.4840	1663	0.01427	0.9981	745
1200	8.7768	9.7133	70.6695	60.0984	16.0339	1528	0.01142	.3623	684
1300	8.8002	10.6921	71.5483	60.8019	14.8971	1418	0.00931	-.1750	633
1400	8.8190	11.4731	72.4293	61.4547	13.8785	1315	0.00733	.6388	589
1500	8.8326	12.3557	73.3119	62.0636	12.9945	1229	0.00618	-.1.0413	551
1600	8.8471	13.2397	74.1959	62.6341	12.2202	1154	0.00518	-1.3945	518
1700	8.8677	14.1249	75.0811	63.1708	11.5362	1087	0.00461	-1.7072	488
1800	8.8866	15.0111	75.9673	63.6774	10.9277	1028	0.00375	-1.9859	462
1900	8.8742	15.8982	76.8544	64.1570	10.3829	975	0.00330	-2.2380	438
2000	8.8807	16.7859	77.7421	64.6123	9.8921	927	0.00287	-2.4618	417
2100	8.8863	17.6742	78.6304	65.0457	9.4478	884	0.00238	-2.6867	398
2200	8.8912	18.5631	79.5193	66.4692	9.0436	844	0.00224	-2.8534	381
2300	8.8955	19.4525	80.4087	66.8546	8.6744	808	0.00193	-3.0244	365
2400	8.8933	20.3432	81.2984	66.2392	8.3858	775	0.00170	-3.1816	350
2500	8.9026	21.2323	82.1885	66.5966	8.0241	744	0.00165	-3.3286	336
2600	8.9056	22.1227	88.0789	66.9458	7.7368	714	0.00152	-3.4908	324
2700	8.9082	23.0134	88.9696	67.2819	7.4696	680	0.00117	-3.5854	318
2800	8.9108	23.1043	84.0605	67.6060	7.2220	668	0.00104	-3.7015	302
2900	8.9127	24.7955	85.7917	67.9187	6.9913	643	0.00107	-3.8098	292
3000	8.9146	25.6869	86.6481	68.2209	6.7759	622	0.00085	-3.9111	283
3100	8.9164	26.5784	87.5246	68.5132	6.5744	602	0.00088	-4.0061	275
3200	8.9180	27.4701	88.4263	68.7963	6.3854	584	0.00063	-4.0955	266
3300	8.9194	28.3620	89.3182	69.0708	6.2078	566	0.00063	-4.1796	258
3400	8.9209	29.2540	90.2102	69.3870	6.0407	550	0.00056	-4.2590	251
3500	8.9220	30.1462	91.1024	69.5956	5.8830	534	0.00057	-4.3341	244
3600	8.9231	31.0384	91.9946	69.8470	5.7341	520	0.00046	-4.4051	238
3700	8.9241	31.9308	92.8870	70.0915	5.5931	506	0.00034	-4.4726	232
3800	8.9250	32.8222	93.7794	70.3295	5.4598	492	0.00035	-4.5365	226
3900	8.9259	33.7138	94.6720	70.5614	5.3229	480	0.00040	-4.5974	221
4000	8.9267	34.6054	95.5646	70.7873	5.2125	468	0.00035	-4.6554	215
4100	8.9274	35.5011	96.4578	71.0078	5.0980	457	0.00039	-4.7106	210
4200	8.9281	36.3939	97.3501	71.2229	4.9888	446	0.00028	-4.7634	206
4300	8.9288	37.2867	98.2429	71.4330	4.8849	436	0.00021	-4.8139	201
4400	8.9294	38.1796	99.1358	71.6383	4.7855	428	0.00023	-4.8622	196
4500	8.9300	39.0726	100.0288	71.8390	4.6906	417	0.00025	-4.9084	192
4600	8.9305	39.9656	100.9218	72.0362	4.5997	407	0.00030	-4.9527	188
4700	8.9310	40.8587	101.8149	72.2273	4.5128	399	0.00028	-4.9963	184
4800	8.9316	41.7613	102.7080	72.4153	4.4294	391	0.00010	-5.0361	181
4900	8.9319	42.6450	103.6012	72.5995	4.3495	383	0.00020	-5.0755	177
5000	8.9323	43.5382	104.4944	72.7800	4.2727	376	0.00027	-5.1138	174
5100	8.9327	44.4315	105.3877	72.9568	4.1989	368	0.00013	-5.1497	171
5200	8.9331	45.3248	106.2810	73.1308	4.1280	361	0.00019	-5.1848	168
5300	8.9334	46.2181	107.1748	73.3005	4.0597	354	0.00014	-5.2187	165
5400	8.9337	47.1114	108.0676	73.4674	3.9940	348	0.00013	-5.2514	161
5500	8.9340	48.0048	108.9610	73.6314	3.9306	341	0.00021	-5.2829	159
5600	8.9343	48.8982	109.8544	73.7924	3.8695	335	0.00023	-5.3135	156
5700	8.9346	49.7917	110.7479	73.9505	3.8105	329	0.00018	-5.3430	153
5800	8.9349	50.6842	111.6414	74.1069	3.7538	324	0.00008	-5.3710	150
5900	8.9351	51.5767	112.5349	74.2886	3.6988	318	0.00020	-5.3992	148
6000	8.9353	52.4723	113.4284	74.4088	3.6454	-----	0.00221	-5.4280	-----

TABLE XXIX—THERMODYNAMIC PROPERTIES OF H (GAS)

[Atomic weight, 1.008]

<i>T</i> (°K)	<i>C_p</i> (cal mole °K)	<i>H_T—H₀</i> (kcal mole)	<i>H_T</i> (kcal mole)	<i>S_T</i> (cal mole °K)
0	4.9680	0	85.3385	
295.16	4.9680	1.4812	86.8097	27.3927
300	4.9680	1.4904	86.8189	27.4232
400	4.9680	1.6872	87.3187	28.8824
500	4.9680	2.4840	87.8125	29.9810
600	4.9680	2.9908	88.3083	30.8667
700	4.9680	3.4776	88.8061	31.5326
800	4.9680	3.9744	89.3029	32.2959
900	4.9680	4.4712	89.7997	32.8811
1000	4.9680	4.9680	90.2965	33.4045
1100	4.9680	5.4648	90.7933	33.8780
1200	4.9680	5.9616	91.2901	34.3108
1300	4.9680	6.4584	91.7869	34.7078
1400	4.9680	6.9552	92.2837	35.0761
1500	4.9680	7.4520	92.7805	35.4188
1600	4.9680	7.9488	93.2773	35.7395
1700	4.9680	8.4456	93.7741	36.0407
1800	4.9680	8.9424	94.2709	36.3246
1900	4.9680	9.4392	94.7677	36.5932
2000	4.9680	9.9360	95.2645	36.8480
2100	4.9680	10.4328	95.7613	37.0904
2200	4.9680	10.9296	96.2581	37.3215
2300	4.9680	11.4264	96.7549	37.5424
2400	4.9680	11.9232	97.2517	37.7538
2500	4.9680	12.4200	97.7485	37.9556
2600	4.9680	12.9168	98.2453	38.1515
2700	4.9680	13.4136	98.7421	38.3390
2800	4.9680	13.9104	99.2389	38.5196
2900	4.9680	14.4072	99.7357	38.6940
3000	4.9680	14.9040	100.2325	38.8624
3100	4.9680	15.4008	100.7293	39.0253
3200	4.9680	15.8976	101.2261	39.1830
3300	4.9680	16.3944	101.7229	39.3359
3400	4.9680	16.8912	102.2197	39.4842
3500	4.9680	17.3880	102.7165	39.6282
3600	4.9680	17.8848	103.2133	39.7681
3700	4.9680	18.3816	103.7101	39.9043
3800	4.9680	18.8784	104.2069	40.0368
3900	4.9680	19.3752	104.7037	40.1688
4000	4.9680	19.8720	105.2005	40.2916
4100	4.9680	20.3688	105.6973	40.4142
4200	4.9680	20.8656	106.1941	40.5340
4300	4.9680	21.3624	106.6909	40.6509
4400	4.9680	21.8592	107.1877	40.7651
4500	4.9680	22.3560	107.6845	40.8787
4600	4.9680	22.8528	108.1813	40.9859
4700	4.9680	23.3496	108.6781	41.0928
4800	4.9680	23.8464	109.1749	41.1973
4900	4.9680	24.3432	109.6717	41.2998
5000	4.9680	24.8400	110.1685	41.4002
5100	4.9680	25.3368	110.6653	41.4985
5200	4.9680	25.8336	111.1621	41.5950
5300	4.9680	26.3304	111.6589	41.6916
5400	4.9680	26.8272	112.1557	41.7825
5500	4.9680	27.3240	112.6525	41.8736
5600	4.9680	27.8208	113.1483	41.9632
5700	4.9680	28.3176	113.6451	42.0511
5800	4.9680	28.8144	114.1429	42.1376
5900	4.9680	29.3112	114.6397	42.2224
6000	4.9680	29.8080	115.1365	42.3059

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TABLE XXX—THERMODYNAMIC PROPERTIES OF H₂ (GAS)

[Molecular weight, 2.016]

T (°K)	C _p (cal mole °K)	H ₂ -H ₈ (kcal mole)	H ₈ (kcal mole)	S _p (cal mole °K)	ΔH° RT	$\delta \left(-\frac{\Delta H^o}{RT} \right) = \frac{-\delta T}{100} \left(\frac{a}{T} + b \right)$		log K	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c}{T} + d \right)$	
						a	b		c	d
298.16	6.892	0	67.4160	31.211	175.8287	-----	-----	71.2098	-----	-----
	6.895	2.0288	69.4407	31.258	174.7610	-----	-----	70.7414	-----	-----
	6.974	2.0385	69.4834	31.288	181.4465	-----	-----	61.7421	-----	-----
	6.993	3.4295	70.1470	33.260	105.4544	-----	-----	40.3099	-----	-----
	600	7.008	4.1286	71.5455	36.084	88.1261	-----	32.6669	-----	-----
700	7.035	4.8315	72.2484	37.187	75.7454	-----	-----	27.1921	-----	-----
800	7.073	5.5374	72.9543	38.108	66.4582	-----	-----	23.0744	-----	-----
900	7.139	6.2480	73.6649	38.946	59.2322	-----	-----	19.3636	-----	-----
1000	7.219	6.9658	74.3827	39.7040	53.4478	51.86	0.02306	17.2883	2291	0.03007
1100	7.310	7.6923	75.1092	40.3963	48.7111	4712	0.02453	15.1755	2087	0.02583
	7.407	8.4281	76.8450	41.0865	44.7599	4318	0.02556	13.4105	1918	0.02315
	7.509	9.1789	76.5908	41.6834	41.4128	3988	0.02637	11.0138	1772	0.02029
	7.615	9.0301	77.3470	42.1938	38.5400	3700	0.02633	10.6275	1648	0.01833
	7.7202	10.6969	78.1138	42.7227	36.0468	3484	0.02605	9.5105	1541	0.01628
1600	7.8232	11.4740	78.8909	43.2243	33.8620	3240	0.02802	8.6311	1447	0.01472
	7.9229	12.2613	79.6782	43.7016	31.9311	3051	0.02400	7.6652	1344	0.01332
	8.0185	13.0594	80.4753	44.1571	30.2121	2884	0.02621	6.8941	1291	0.01173
	8.1083	13.8648	81.2817	44.5931	28.6716	2734	0.02770	6.2020	1225	0.01060
	8.1949	14.6800	82.0969	45.0112	27.2829	2600	0.02631	5.5798	1168	0.00946
2100	8.2762	15.5036	82.9208	45.4130	26.0245	2478	0.01954	5.0151	1112	0.00866
	8.3587	16.3351	83.7520	45.7998	24.8788	2367	0.01887	4.5010	1063	0.00793
	8.4274	17.1741	84.5910	46.1728	23.8308	2267	0.01752	4.0309	1018	0.00733
	8.4977	18.0204	85.4373	46.5329	22.8887	2174	0.01890	3.5904	978	0.00640
	8.5647	18.8735	86.2904	46.8812	21.9822	2089	0.01604	3.2018	940	0.00586
2600	8.6288	19.7331	87.1500	47.2183	21.1627	2011	0.01819	2.9344	905	0.00541
	8.6896	20.5901	88.0160	47.5451	20.4027	1988	0.01466	2.4988	873	0.00481
	8.7479	21.4709	88.8878	47.8622	19.6959	1870	0.01417	2.1772	843	0.00441
	8.8042	22.3485	89.7654	48.1702	19.0369	1807	0.01377	1.8821	815	0.00403
	8.8587	23.2317	90.6488	48.4896	18.4208	1748	0.01323	1.6364	789	0.00348
3100	8.9118	24.1202	91.5871	48.7609	17.8437	1693	0.01294	1.3482	764	0.00355
	8.9636	25.0140	92.4309	49.0447	17.3017	1640	0.01283	1.1089	741	0.00326
	9.0143	25.9129	93.2938	49.3213	16.7919	1591	0.01268	.8781	719	0.00313
	9.0639	26.8168	94.2337	49.5911	16.3113	1546	0.01219	.6635	699	0.00279
	9.1125	27.7256	95.1425	49.8545	15.8574	1502	0.01208	.4810	680	0.00241
3600	9.1602	28.6392	96.0561	50.1119	15.4281	1461	0.01184	0.2807	662	0.00228
	9.2070	29.5576	96.3745	50.3635	16.0214	1423	0.01183	0.1985	644	0.00223
	9.2529	30.4906	97.3875	50.6097	14.6364	1383	0.01132	0.1832	628	0.00197
	9.2979	31.4081	98.3260	50.8506	14.2687	1351	0.01125	0.2462	613	0.00175
	9.3421	32.3401	99.7670	51.0866	13.9197	1318	0.01104	0.4012	598	0.00165
4100	9.3856	33.2785	100.0934	51.3178	13.5872	1287	0.01067	-0.5487	584	0.00145
	9.4283	34.2172	101.5241	51.5445	13.2701	1287	0.01057	-0.6902	571	0.00131
	9.4704	35.1621	102.5700	51.7688	12.9672	1229	0.01038	-0.8233	558	0.00118
	9.5118	36.1113	103.5282	51.9850	12.6775	1201	0.01031	-0.9518	546	0.00097
	9.5526	37.0645	104.4814	52.1932	12.4003	1175	0.01017	-1.0738	535	0.00080
4600	9.6928	38.0217	105.4386	52.4096	12.1347	1150	0.01002	-1.1907	524	0.00071
	9.6324	38.9830	106.3999	52.6104	11.8900	1127	0.00971	-1.3029	514	0.00042
	9.6714	39.9482	107.3651	52.8196	11.6855	1104	0.00969	-1.4104	503	0.00045
	9.7099	40.9173	108.3342	53.0194	11.4005	1082	0.00950	-1.5135	494	0.00030
	9.7479	41.8901	109.3070	53.2159	11.1746	1061	0.00936	-1.5126	484	0.00020
5100	9.7858	42.8668	110.2837	53.4093	10.9572	1041	0.00931	-1.7077	475	0.00016
	9.8222	43.8472	111.2641	53.5997	10.7477	1021	0.00916	-1.7922	466	0.00018
	9.8586	44.8312	112.2491	53.7871	10.5499	1003	0.00906	-1.8873	458	-0.00001
	9.8945	45.8189	113.2358	53.9717	10.3511	985	0.00891	-1.9721	450	-0.00002
	9.9299	46.8101	114.2270	54.1536	10.1631	967	0.00882	-2.0639	442	-0.00013
5600	9.9649	47.8048	115.2217	54.3328	9.9816	951	0.00878	-2.1327	434	-0.00014
	9.9994	48.8031	116.2200	54.5095	9.8660	934	0.00867	-2.2057	427	-0.00012
	10.0334	49.8047	117.2216	54.6837	9.6368	919	0.00854	-2.2822	420	-0.00020
	10.0670	50.8097	118.2266	54.8556	9.4720	904	0.00843	-2.3531	413	-0.00033
	10.1001	51.8181	119.2350	55.0250	9.3129	-----	-----	-2.4216	-----	-----

TABLE XXXI—THERMODYNAMIC PROPERTIES OF HCl (GAS)

[Molecular weight, 36.465]

<i>T</i> (°K)	<i>C_v</i> (cal mole °K)	<i>H₂-H₃</i> (kcal mole)	<i>H₂</i> (kcal mole)	<i>S_T</i> (cal mole °K)	$\frac{\Delta H^o}{RT}$	$s\left(\frac{\Delta H^o}{RT}\right) = \frac{-\delta T}{100} \left(\frac{a}{T} + b\right)$	$\log K'$	$s \log K = \frac{-\delta T}{100} \left(\frac{c}{T} + d\right)$	
								<i>a</i>	<i>b</i>
0	6.96	0	15.5926	44.617	174.1180			70.7896	
298.16	6.96	2.0648	17.6574	44.661	173.6598			70.2960	
300	6.96	2.0778	17.6704	44.661	173.6598			61.4775	
400	6.97	2.7740	18.3866	46.656	180.2118			40.1522	
500	7.00	3.4730	19.0566	48.224	104.5100				
600	7.07	4.1786	19.7692	49.506	87.8737			82.5758	
700	7.17	4.8881	20.4807	50.603	75.1291			27.1488	
800	7.29	5.6112	21.2038	51.598	65.0366			23.0623	
900	7.42	6.3468	21.9394	52.434	58.7762			19.8761	
1000	7.554	7.0960	22.6878	53.2220	58.0404	5124	0.04262	17.3201	2274
1100	7.690	7.8572	23.4498	53.9484	48.3394	4861	0.04023	15.2234	2071
1200	7.819	8.6326	24.2252	54.6220	44.4150	4277		13.4710	.02145
1300	7.938	9.4205	25.0131	55.2538	41.0864	3952	.03354	11.9868	.01876
1400	8.046	10.2197	25.8123	56.8498	38.2320	3676	.02908	10.7107	.01867
1500	8.140	11.0290	26.6216	56.4041	35.7573	3437	.02495	9.6027	.01605
1600	8.221	11.8470	27.4396	56.9320	33.5792	3227	0.02197	8.6314	.01331
1700	8.292	12.6727	28.2553	57.4225	31.6590	3040	.02031	7.7728	.01172
1800	8.353	13.5052	29.0778	57.9084	29.9198	2871	.0245	7.0683	.01036
1900	8.426	14.3444	29.8370	58.3621	28.4188	2723	.01870	6.3232	.00960
2000	8.498	15.1901	30.7827	58.7988	27.0881	2530	.01717	5.7056	.00865
2100	8.545	16.0417	31.6343	59.2114	25.7876	2471	0.01802	5.1461	1103
2200	8.595	16.8987	32.4913	59.6100	24.6494	2361	.01898	4.6367	.00710
2300	8.643	17.7606	33.3532	59.9882	23.6089	2262	.01240	4.1709	.00667
2400	8.685	18.6270	34.2106	60.3610	22.6549	2169	.01190	3.7434	.00620
2500	8.726	19.4976	35.0902	60.7172	21.7745	2086	.01089	3.3486	.00582
2600	8.762	20.3720	35.9648	61.0602	20.9618	2007	0.00997	2.9857	896
2700	8.796	21.2499	36.8425	61.3915	20.2085	1934	.00939	2.6454	.00513
2800	8.829	22.1311	37.7237	61.7120	19.5054	1868	.00848	2.3347	.00471
2900	8.855	23.0155	38.6081	62.0223	18.8558	1805	.00783	2.0424	.00443
3000	8.885	23.9028	39.4952	62.3221	18.2463	1745	.00720	1.7693	.00409
3100	8.912	24.7925	40.3851	62.6148	17.6756	1691	0.00706	1.5136	.00375
3200	8.937	25.6849	41.2775	62.8982	17.1401	1639	.00683	1.2736	.00368
3300	8.961	26.5788	42.1724	63.1736	16.6366	1591	.00626	1.0479	.00348
3400	8.983	27.4770	43.0696	63.4414	16.1624	1545	.00607	.8353	.00327
3500	9.004	28.3764	43.9690	63.7021	15.7149	1502	.00573	.6346	.00321
3600	9.024	29.2778	44.8704	63.9580	15.2919	1462	0.00527	0.4450	.00284
3700	9.043	30.1811	45.7737	64.2035	14.8915	1421	.00465	.2654	.00283
3800	9.063	31.0864	46.6790	64.4450	14.5119	1386	.00502	.0952	.00273
3900	9.081	31.9926	47.5862	64.6806	14.1815	1352	.00480	-.0645	.00270
4000	9.098	32.8026	48.4932	64.9108	13.8089	1318	.00474	-.2202	.00250
4100	9.115	33.8132	49.4058	65.1356	13.4827	1287	0.00437	-.3666	.578
4200	9.131	34.7265	50.3181	65.3854	13.1719	1256	.00451	-.0680	.555
4300	9.147	35.6394	51.2320	65.6705	12.8763	1228	.00421	-.6391	.551
4400	9.162	36.5549	52.1475	65.9710	12.5920	1202	.00379	-.7663	.538
4500	9.178	37.4718	53.0644	66.9870	12.3211	1174	.00408	-.8878	.527
4600	9.191	38.3901	53.9827	66.1888	12.0618	1150	0.00372	-.1.0042	.516
4700	9.205	39.3089	54.9025	66.3867	11.8134	1127	.00341	-.1.1167	.505
4800	9.218	40.2311	55.8237	66.5806	11.5732	1102	.00380	-.1.2226	.495
4900	9.232	41.1538	56.7452	66.7208	11.3465	1081	.00340	-.1.3252	.485
5000	9.245	42.0774	57.6700	66.9574	11.1269	1060	.00336	-.1.4238	.476
5100	9.257	43.0025	58.6051	67.1496	10.9157	1038	0.00348	-.1.5186	.467
5200	9.270	43.9259	59.5215	67.3205	10.7126	1020	.00325	-.1.6008	.457
5300	9.282	44.8565	60.4491	67.4972	10.5169	1001	.00313	-.1.6976	.449
5400	9.294	45.7863	61.3779	67.6708	10.3284	982	.00326	-.1.7822	.441
5500	9.306	46.7163	62.3079	67.8415	10.1466	964	.00316	-.1.8638	.433
5600	9.318	47.6465	63.2391	68.0093	9.9713	947	0.00326	-.1.9425	.429
5700	9.330	48.5789	64.1715	68.1743	9.8019	930	.00326	-.2.0185	.419
5800	9.342	49.5125	65.1051	68.3387	9.6333	914	.00328	-.2.0919	.412
5900	9.354	50.4473	66.0399	68.4965	9.4801	900	.00300	-.2.1629	.405
6000	9.365	51.3832	66.9758	68.6538	9.3271	-----	-----	-.2.2315	-----

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TABLE XXXII—THERMODYNAMIC PROPERTIES OF HF (GAS)

[Molecular weight, 20.008]

T (°K)	C_p (cal mole °K)	$H_F - H_3$ (cal mole)	H_F (cal mole)	S_F (cal mole °K)	$\frac{\Delta H^\circ}{RT}$	$\delta \left(\frac{-\Delta H^\circ}{RT} - \frac{-\delta T}{100} \left(\frac{a}{T} + b \right) \right)$		$\log K'$	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c}{T} + d \right)$	
						a	b		c	d
298.16	6.9615	0	0	41.5114	227.1879			93.4523		
	6.9615	2.0553	2.0553	41.5542	225.7754			92.8472		
	6.9615	2.0681	2.0681	43.5575	162.7899			68.3058		
	6.9652	2.7645	2.7645	43.5575	136.1421			53.5438		
	6.9715	3.4613	3.4613	45.1124						
600	6.9858	4.1592	4.1592	46.8848	113.7233			43.6784		
	7.0150	4.8392	4.8392	47.4639	97.7048			38.6149		
	7.0237	5.5631	5.5631	48.4088	85.6849			31.3051		
	7.1290	6.2727	6.2727	49.2396	76.3816			27.1680		
	7.2108	6.9897	6.9897	49.9950	68.8439	6714	0.02746	23.8476	2659	0.03070
1100	7.3038	7.7154	7.7154	50.0866	62.7128	6103	0.02817	21.1269	2694	0.02600
	7.4035	8.4508	8.4508	51.3204	57.5988	5594	0.02852	18.5680	2473	.02359
	7.5059	9.1962	9.1962	51.9231	53.2672	5164	0.02823	16.9291	2267	.02033
	7.6084	9.9520	9.9520	52.4881	49.5504	4797	0.02700	15.2752	2126	.01847
	7.7084	10.7178	10.7178	53.0114	46.3254	4479	0.02573	13.8304	1987	.01653
1600	7.8048	11.4995	11.4995	53.5120	43.5003	4201	0.02452	12.6910	1366	0.01455
	7.8967	12.2785	12.2785	53.9879	41.0046	3956	0.02332	11.4688	1788	.01333
	7.9836	13.0728	13.0728	54.4417	38.7835	3739	0.02181	10.4788	1682	.01236
	8.0637	13.8760	13.8760	54.8756	36.7940	3545	0.02080	9.6917	1577	.01100
	8.1427	14.6854	14.6854	55.2913	35.0012	3370	0.01904	8.7923	1500	.01011
2100	8.2150	15.5033	15.5033	55.8903	33.3774	3213	0.01790	8.0678	1430	0.00920
	8.2628	16.3232	16.3232	56.0740	31.8665	3064	0.01655	7.4088	1367	.00835
	8.3464	17.1597	17.1597	56.4436	30.6496	2938	0.01549	6.9059	1309	.00768
	8.4061	17.9973	17.9973	56.8001	29.3090	2618	0.01450	6.2528	1226	.00710
	8.4628	18.8407	18.8407	57.1444	28.1673	2707	0.01386	5.7483	1206	.00686
2600	8.5182	19.6896	19.6896	57.4773	27.1123	2605	0.01289	5.2726	1161	0.00630
	8.5650	20.5438	20.5438	57.7995	26.1346	2510	0.01247	4.8343	1119	.00598
	8.6124	21.4025	21.4025	58.1119	25.2257	2423	0.01148	4.4507	1080	.00549
	8.6672	22.2680	22.2680	58.4149	24.3787	2341	0.01087	4.0528	1044	.00510
	8.7000	23.1388	23.1388	58.7091	23.5875	2284	0.01058	3.6997	1010	.00479
3100	8.7408	24.0050	24.0050	58.9951	22.8466	2193	0.00999	3.3691	979	0.00426
	8.7797	24.8819	24.8819	59.2732	22.1513	2126	0.00946	3.0589	949	0.00402
	8.8169	25.7617	25.7617	59.5439	21.4976	2062	0.00933	2.7673	921	.00382
	8.8527	26.6452	26.6452	59.8077	20.8818	2003	0.00881	2.4926	895	.00349
	8.8872	27.5322	27.5322	60.0648	20.3007	1947	0.00847	2.2334	870	.00333
3600	8.9205	28.4226	28.4226	60.3156	19.7514	1894	0.00821	1.9684	847	0.00308
	8.9528	29.3162	29.3162	60.5605	19.2313	1843	0.00820	1.7564	824	.00296
	8.9842	30.2131	30.2131	60.7996	18.7381	1795	0.00794	1.5268	804	.00265
	9.0151	31.1130	31.1130	61.0384	18.2699	1750	0.00780	1.3278	784	.00240
	9.0463	32.0161	32.0161	61.2820	17.8246	1707	0.00756	1.1294	765	.00231
4100	9.0750	32.9221	32.9221	61.4558	17.4007	1666	0.00733	0.9405	746	0.00228
	9.1043	33.8310	33.8310	61.7048	16.9967	1624	0.00756	7.606	730	.00203
	9.1336	34.7429	34.7429	61.9194	16.6111	1588	0.00759	5.8888	713	.00195
	9.1631	35.6578	35.6578	62.1297	16.2426	1551	0.00773	4.2428	697	.00191
	9.1936	36.5756	36.5756	62.3359	15.8902	1512	0.00849	2.2680	682	.00174
4600	9.2271	37.4966	37.4966	62.5384	15.5528	1479	0.00872	0.1180	668	0.00167
	9.2623	38.4211	38.4211	62.7872	15.2294	1446	0.00915	-0.2558	654	.00165
	9.2978	39.3491	39.3491	63.0326	14.9190	1416	0.00902	-1.636	641	.00138
	9.3335	40.2807	40.2807	63.1248	14.6210	1387	0.00910	-2.2988	629	.00130
	9.3690	41.2158	41.2158	63.1836	14.3345	1360	0.00898	-4.2299	616	.00132
5100	9.4040	42.1545	42.1545	63.4904	14.0589	1334	0.00876	-0.5450	604	0.00125
	9.4386	43.0968	43.0968	63.6824	13.7038	1309	0.00872	-0.6624	592	.00130
	9.4728	44.0422	44.0422	63.8525	13.3579	1286	0.00844	-0.7754	582	.00112
	9.5061	44.9911	44.9911	64.0399	13.2015	1262	0.00845	-0.8843	571	.00118
	9.5391	45.9434	45.9434	64.2148	13.0336	1240	0.00817	-0.9893	561	.00112
5600	9.5718	46.8969	46.8969	64.3868	12.8240	1218	0.00822	-1.0906	551	0.00103
	9.6040	47.8577	47.8577	64.5565	12.6021	1198	0.00795	-1.1883	541	.00102
	9.6368	48.8197	48.8197	64.7238	12.3876	1177	0.00801	-1.2626	532	.00103
	9.6673	49.7648	49.7648	64.8888	12.1801	1158	0.00780	-1.3738	524	.00097
	9.6986	50.7531	50.7531	65.0515	11.9793			-1.4621		

TABLE XXXIII—THERMODYNAMIC PROPERTIES OF H₂O (GAS)

[Molecular weight, 18.016]

T (°K)	C _s (cal/mole °K)	H ₂ -H ₂ ^o (kcal)	H ₂ (kcal)	S _T (cal/mole °K)	$\frac{\Delta H^o}{RT}$	$\delta \left(-\frac{\Delta H^o}{RT} \right) = \frac{-\delta T}{100} \left(\frac{c+b}{T} \right)$		log K	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c+d}{T} \right)$	
						a	b		c	d
0		0	11.3311	45.106	373.2200	-----	-----	151.5648	-----	-----
298.16	8.025	2.8677	13.6968	45.154	370.9541	-----	-----	160.5708	-----	-----
300	8.026	2.8820	13.7131	45.154	370.9541	-----	-----	110.2372	-----	-----
400	8.185	8.1940	14.5251	47.490	279.0956	-----	-----	85.8609	-----	-----
500	8.415	4.0255	15.3566	49.344	223.9524	-----	-----	-----	-----	-----
600	8.677	4.8822	16.2183	50.903	187.1673	-----	-----	69.7280	-----	-----
700	8.959	5.7715	17.1026	52.269	160.5663	-----	-----	58.0956	-----	-----
800	9.254	6.6896	18.0207	53.490	141.1213	-----	-----	49.3548	-----	-----
900	9.559	7.6347	18.9538	54.599	125.7485	-----	-----	42.6361	-----	-----
1000	9.861	8.6080	19.9391	55.6180	113.4355	11.015	0.07316	87.0674	4575	0.05158
1100	10.145	9.6063	20.9394	56.5712	103.6487	10.019	0.06833	32.5840	4439	0.04493
1200	10.413	10.6862	21.9673	57.4654	94.9312	9.188	0.06491	28.8399	4076	0.03902
1300	10.668	11.6902	22.0213	58.3090	87.7986	8.486	0.06187	25.6865	3768	0.03457
1400	10.909	12.7891	24.1002	59.1084	81.6788	7.886	0.05866	22.9395	3805	0.03013
1500	11.134	13.8712	25.2023	59.8687	76.3815	7.366	0.05315	20.6727	3276	0.02690
1600	11.343	14.9951	26.3262	60.5939	71.7046	6.913	0.04833	18.4983	3075	0.02428
1700	11.534	16.1839	27.4700	61.2873	67.8898	6.514	0.04401	16.6652	2598	0.02200
1800	11.708	17.8010	28.6321	61.9516	68.9267	6.180	0.03999	15.0332	2741	0.01957
1900	11.865	18.4797	29.8108	62.5887	60.6450	5.843	0.03590	13.5710	2600	0.01770
2000	12.008	19.6733	31.0044	63.2010	57.6876	5.557	0.03271	12.2533	2474	0.01570
2100	12.138	20.8806	32.2117	63.7900	55.0087	5.299	0.02966	11.0595	2359	0.01423
2200	12.266	22.1003	33.4814	64.2574	52.5704	5.064	0.02686	9.9730	2255	0.01277
2300	12.384	23.8813	34.6624	64.9045	50.3418	4.849	0.02488	8.9798	2160	0.01150
2400	12.493	24.5727	35.9038	65.4328	48.2367	4.658	0.02220	8.0688	2072	0.01080
2500	12.554	26.8235	37.1546	65.0434	46.4133	4.471	0.02049	7.2259	1991	0.00993
2600	12.638	27.0831	38.4142	66.4374	44.6732	4.304	0.01883	6.4532	1916	0.00927
2700	12.715	28.3808	39.6819	66.9159	48.0605	4.149	0.01691	5.7348	1846	0.00898
2800	12.786	29.6258	40.9569	67.3798	41.6618	4.005	0.01547	5.0681	1781	0.00856
2900	12.852	30.9077	42.2388	67.8284	40.1853	3.871	0.01407	4.4434	1721	0.00803
3000	12.913	32.1960	43.5271	68.2661	38.8609	3.747	0.01239	3.8617	1666	0.00728
3100	12.968	33.4900	44.8211	68.6004	37.6398	3.630	0.01113	3.3170	1613	0.00694
3200	13.018	34.7893	46.1204	69.1029	36.4943	3.520	0.00993	2.8060	1584	0.00658
3300	13.064	36.0834	47.4245	69.5042	35.4177	3.417	0.00890	2.3255	1517	0.00612
3400	13.107	37.4020	48.7331	69.8949	34.4038	3.320	0.00788	1.8729	1473	0.00624
3500	13.147	38.7147	50.0458	70.2754	33.4473	3.228	0.00703	1.4468	1431	0.00610
3600	13.184	40.0312	51.3623	70.6453	32.5436	3.142	0.00601	1.0422	1392	0.00588
3700	13.218	41.3613	52.6824	71.0060	31.6884	3.059	0.00550	.8601	1355	0.00572
3800	13.250	42.6747	54.0058	71.3603	30.8719	2.981	0.00484	.2978	1320	0.00564
3900	13.280	44.0012	55.3328	71.7054	30.1087	2.907	0.00425	-.0462	1297	0.00525
4000	13.308	45.3306	56.6617	72.0420	29.3777	2.836	0.00379	-.2732	1265	0.00520
4100	13.334	46.6627	57.9938	72.3710	28.6522	2.769	0.00321	-.6843	1266	0.00480
4200	13.358	47.9973	59.3284	72.6926	28.0197	2.705	0.00283	-.9812	1196	0.00460
4300	13.381	49.3343	60.6554	73.0071	27.3878	2.648	0.00232	-1.2643	1170	0.00449
4400	13.403	50.6735	62.0046	73.3150	26.7845	2.584	0.00238	-1.5247	1144	0.00438
4500	13.424	52.0148	63.3469	73.6164	26.2079	2.528	0.00204	-1.7933	1119	0.00434
4600	13.444	53.3582	64.6893	73.9117	25.6663	2.478	0.00203	-2.0409	1095	0.00412
4700	13.484	54.7036	66.0347	74.2011	25.1281	2.421	0.00198	-2.2780	1073	0.00398
4800	13.483	55.0610	67.3821	74.4847	24.6218	2.371	0.00182	-2.5055	1051	0.00381
4900	13.502	57.4002	68.7313	74.7829	24.1361	2.323	0.00170	-2.7238	1030	0.00370
5000	13.521	58.7414	70.0526	75.0359	23.6698	2.276	0.00158	-2.9335	1010	0.00356
5100	13.540	60.1044	71.4355	75.3088	23.2217	2.232	0.00177	-3.1351	991	0.00342
5200	13.559	61.4504	72.7905	75.5669	22.7907	2.189	0.00168	-3.3291	973	0.00322
5300	13.577	62.8162	74.1473	75.8264	22.3760	2.148	0.00172	-3.5159	956	0.00318
5400	13.596	64.1748	75.5059	76.0794	21.9765	2.108	0.00163	-3.6959	938	0.00305
5500	13.614	65.5353	76.8664	76.3290	21.5916	2.070	0.00166	-3.8695	921	0.00304
5600	13.633	66.8977	78.2288	76.5745	21.2203	2.033	0.00163	-4.0370	905	0.00293
5700	13.651	68.2619	79.5930	76.8159	20.8620	1.998	0.00162	-4.1887	890	0.00285
5800	13.669	69.6279	80.9590	77.0535	20.5169	1.963	0.00169	-4.3530	875	0.00279
5900	13.687	70.9957	82.3268	77.2673	20.1816	1.930	0.00163	-4.5061	860	0.00277
6000	13.705	72.3653	83.6964	77.5175	19.8583	-----	-----	-4.6522	-----	-----

TABLE XXXIV—THERMODYNAMIC PROPERTIES OF
 e^- (ELECTRON GAS)[Atomic weight, 5.4847x10⁻⁴]

T (°K)	C_p^o (cal/mole °K)	$H_f^o - H_{f,0}^o$ (kcal/mole)	H_f^o (kcal/mole)	S_f^o (cal/mole °K)
0	4.9880	0	60.0000	4.9882
298.16	4.9880	1.4812	61.4812	5.0188
300	4.9880	1.4904	61.4904	5.0188
400	4.9880	1.9872	61.9872	6.4480
500	4.9880	2.4840	62.4840	7.5588
600	4.9880	2.9808	62.9808	8.4623
700	4.9880	3.4776	63.4776	9.2281
800	4.9880	3.9744	63.9744	9.8915
900	4.9880	4.4712	64.4712	10.4706
1000	4.9880	4.9680	64.9680	11.0001
1100	4.9880	5.4648	65.4648	11.4736
1200	4.9880	5.9616	65.9616	11.9058
1300	4.9880	6.4584	66.4584	12.3035
1400	4.9880	6.9552	66.9552	12.6717
1500	4.9880	7.4520	67.4520	13.0144
1600	4.9880	7.9488	67.9488	13.3350
1700	4.9880	8.4456	68.4456	13.6382
1800	4.9880	8.9424	68.9424	13.9202
1900	4.9880	9.4392	69.4392	14.1888
2000	4.9880	9.9360	69.9360	14.4436
2100	4.9880	10.4328	70.4328	14.6860
2200	4.9880	10.9296	70.9296	14.9171
2300	4.9880	11.4264	71.4264	15.1879
2400	4.9880	11.9232	71.9232	15.3494
2500	4.9880	12.4200	72.4200	15.5523
2600	4.9880	12.9168	72.9168	15.7470
2700	4.9880	13.4136	73.4136	15.9345
2800	4.9880	13.9104	73.9104	16.1132
2900	4.9880	14.4072	74.4072	16.2895
3000	4.9880	14.9040	74.9040	16.4579
3100	4.9880	15.4008	75.4008	16.6208
3200	4.9880	15.8976	75.8976	16.7786
3300	4.9880	16.3944	76.3944	16.9314
3400	4.9880	16.8912	76.8912	17.0797
3500	4.9880	17.3880	77.3880	17.2287
3600	4.9880	17.8848	77.8848	17.3837
3700	4.9880	18.3816	78.3816	17.4968
3800	4.9880	18.8784	78.8784	17.6323
3900	4.9880	19.3752	79.3752	17.7614
4000	4.9880	19.8720	79.8720	17.8871
4100	4.9880	20.3688	80.3688	18.0098
4200	4.9880	20.8656	80.8656	18.1295
4300	4.9880	21.3624	81.3624	18.2484
4400	4.9880	21.8592	81.8592	18.3606
4500	4.9880	22.3560	82.3560	18.4723
4600	4.9880	22.8528	82.8528	18.5815
4700	4.9880	23.3496	83.3496	18.6888
4800	4.9880	23.8464	83.8464	18.7920
4900	4.9880	24.3432	84.3432	18.8953
5000	4.9880	24.8400	84.8400	18.9957
5100	4.9880	25.3368	85.3368	19.0941
5200	4.9880	25.8336	85.8336	19.1906
5300	4.9880	26.3304	86.3304	19.2852
5400	4.9880	26.8272	86.8272	19.3781
5500	4.9880	27.3240	87.3240	19.4692
5600	4.9880	27.8208	87.8208	19.5597
5700	4.9880	28.3176	88.3176	19.6467
5800	4.9880	28.8144	88.8144	19.7381
5900	4.9880	29.3112	89.3112	19.8180
6000	4.9880	29.8080	89.8080	19.9016

TABLE XXXV—THERMODYNAMIC PROPERTIES OF F⁻ (GAS)

[Atomic weight, 19.00]

<i>T</i> (°K)	<i>C_p</i> (cal mole°K)	<i>H₂ - H₀</i> (kcal mole)	<i>H₂</i> (kcal mole)	<i>S_f</i> (cal mole°K)	$\frac{\Delta H^{\circ}}{RT}$	$\delta \left(\frac{\Delta H^{\circ}}{RT} \right) = \frac{-\delta T}{100} \left(\frac{c}{T} + b \right)$	log K	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c}{T} + d \right)$	
								<i>a</i>	<i>b</i>
298.16	4.9680	0	11.9781	34.7682	165.1619	.....	69.6905	.....	.....
	4.9680	1.4512	13.4593	34.7682	164.1656	.....	69.6105	.....	.....
	4.9680	1.4904	13.4635	34.7682	164.1656	.....	51.6419	.....	.....
	4.9680	1.9872	13.9653	38.2280	123.8037	.....	40.3814	.....	.....
	4.9680	2.4340	14.4621	37.3366	99.5784	.....	.....	.....	.....
600	4.9680	2.9808	14.9589	38.3423	83.4222	.....	33.6357	.....	.....
	4.9680	3.4776	15.4557	89.0081	71.8780	.....	26.1472	.....	.....
	4.9680	3.9744	15.9525	39.6715	63.2172	.....	24.8355	.....	.....
	4.9680	4.4712	16.4493	40.2568	56.4793	.....	21.4775	.....	.....
	4.9680	4.9679	16.9460	40.7801	51.0877	4849	0.00402	19.0187	2164
	4.9680	5.4647	17.4428	41.2386	46.6755	4409	0.00333	16.9968	1972
1200	4.9680	5.9615	17.9396	41.6858	42.9820	4042	.00297	15.8035	1312
	4.9680	6.4583	18.4364	42.0835	39.8835	3732	.00219	15.8638	1377
	4.9680	6.9551	18.9332	42.4817	37.2179	3466	.00193	12.5234	1661
	4.9680	7.4519	19.4300	42.7944	34.9063	3235	.00172	11.5432	1461
	4.9680	7.9437	19.9268	43.1150	32.8817	3034	0.00110	10.5936	1873
1800	4.9680	8.4466	20.4226	43.4162	31.0959	2855	.00129	9.7516	1299
	4.9680	8.9423	20.9204	43.7002	29.8085	2897	.00103	8.9935	1227
	4.9680	9.4391	21.4172	43.9658	28.0880	2555	.00110	8.3235	1185
	4.9680	9.9359	21.9140	44.2236	26.8094	2428	.00061	7.7121	1110
	4.9680	10.4327	22.4108	44.4860	25.6326	2312	0.00079	7.1564	1059
2400	4.9680	10.9295	22.9076	44.9791	24.6009	2207	.00073	6.6489	1014
	4.9680	11.4263	23.4044	44.9179	23.6406	2112	.00040	6.1833	972
	4.9680	11.9231	23.9012	45.1294	22.7602	2024	.00030	5.7045	934
	4.9680	12.4100	24.3980	45.3322	21.9503	1943	.00039	5.3582	899
	4.9680	12.9167	24.8948	45.5270	21.2026	1888	0.00045	4.9907	866
3000	4.9680	13.4135	25.3916	45.7145	20.6103	1799	.00040	4.6499	826
	4.9680	13.9103	25.8884	45.8952	19.8674	1735	.00032	4.3801	808
	4.9680	14.4071	26.3852	46.0685	19.2688	1676	.00037	4.0310	782
	4.9680	14.9039	26.8820	46.2379	18.7101	1619	.00014	3.7523	753
	4.9680	15.4007	27.3788	46.4008	18.1874	1567	0.00031	3.4896	735
3600	4.9680	15.8975	27.8756	46.5586	17.6974	1518	.00030	3.2423	714
	4.9680	16.3943	28.3724	46.7114	17.2271	1472	.00036	3.0069	694
	4.9680	16.8911	28.8692	46.8598	16.8038	1420	.00021	2.7882	673
	4.9680	17.3879	29.3660	47.0088	16.3953	1388	.00024	2.5792	658
	4.9680	17.8847	29.8628	47.1437	16.0095	1350	0.00014	2.3810	641
4200	4.9680	18.3815	30.3596	47.2938	15.6445	1313	.00027	2.1927	625
	4.9680	18.8783	30.8564	47.4123	15.2987	1279	.00006	2.0125	610
	4.9680	19.3751	31.3532	47.5414	14.9707	1245	.00010	1.8428	595
	4.9680	19.8719	31.8500	47.6672	14.6591	1215	.00016	1.6780	582
	4.9680	20.3687	32.3468	47.7938	14.3626	1185	0.00026	1.5243	569
4800	4.9680	20.8655	32.8436	47.9095	14.0502	1157	.00013	1.3766	557
	4.9680	21.3623	33.3404	48.0264	13.8110	1130	.00018	1.2330	545
	4.9680	21.8591	33.8372	48.1406	13.5540	1104	.00017	1.0964	534
	4.9680	22.3559	34.3340	48.2523	13.3085	1080	.00012	.9653	524
	4.9680	22.8527	34.8308	48.3615	13.0736	1057	0.00001	0.8894	514
5400	4.9680	23.3495	35.3276	48.4883	12.8457	1034	.00008	.7183	0.11473
	4.9680	23.8463	35.8244	48.5729	12.6332	1018	.00007	.6018	0.11429
	4.9680	24.3431	36.3212	48.6754	12.4264	992	.00000	.4506	0.11415
	4.9680	24.8399	36.8180	48.7757	12.2280	972	.00011	.3815	0.11365
	4.9680	25.3367	37.3148	48.8741	12.0373	953	0.00018	0.2771	488
6000	4.9680	25.8335	37.8116	48.9706	11.8339	934	.00017	0.1764	460
	4.9680	26.3303	38.3084	49.0652	11.6775	917	.00009	.0791	433
	4.9680	26.8271	38.8052	49.1881	11.5076	900	.00016	-.0151	415
	4.9680	27.3239	39.3020	49.2492	11.3438	883	.00012	-.1061	409
	4.9680	27.8207	39.7988	49.3387	11.1860	868	0.00012	-.1943	382
6600	4.9680	28.3175	40.2956	49.4287	11.0336	853	.00003	-.2797	425
	4.9680	28.8143	40.7924	49.5121	10.8865	838	.00007	-.3624	419
	4.9680	29.3111	41.2892	49.5980	10.7444	824	.00007	-.4427	413
	4.9680	29.8079	41.7860	49.6815	10.6070	-----	-.5207	----	0.00917

TABLE XXXVI—THERMODYNAMIC PROPERTIES OF Li+(GAS)

[Atomic weight, 6.940]

T (°K)	C_p (cal/mole °K)	$H_f^0 - H_g^0$ (kcal/mole)	H_f^0 (kcal/mole)	S_f^0 (cal/mole °K)	$-\frac{\Delta H^0}{RT}$	$\delta \left(-\frac{\Delta H^0}{RT} \right) - \frac{-\delta T}{100} \left(\frac{a}{T} + b \right)$	log K	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c}{T} + d \right)$		
								c	d	
0 298.16	4.9680	0	230.7290	31.7662	-211.6052	-----	-91.0680	-----	-----	
	4.9680	1.4812	232.2102	31.7662	-210.2229	-----	-90.5026	-----	-----	
	4.9680	1.4903	232.2103	31.7667	-210.2229	-----	-67.6371	-----	-----	
	4.9680	1.9871	232.7161	33.2269	-168.2922	-----	-63.8820	-----	-----	
	4.9680	2.4529	233.2129	34.3345	-127.1337	-----	-----	-----	-----	
600 700 800 900 1000	4.9680	2.9807	283.7097	35.2403	-106.3814	-----	-44.6436	-----	-----	
	4.9680	3.4775	284.2056	36.0061	-91.5241	-----	-38.0325	-----	-----	
	4.9680	3.9743	284.7083	36.6895	-80.3961	-----	-33.0546	-----	-----	
	4.9680	4.4711	285.2001	37.2546	-71.7410	-----	-29.1679	-----	-----	
	4.9680	4.9679	285.6969	37.7780	-64.6169	-6232	0.00038	-26.0464	-2761	-0.03380
1100 1200 1300 1400 1500	4.9680	5.4847	236.1937	38.2615	-59.1518	-5865	-0.00017	-23.4826	-2515	-0.04897
	4.9680	5.9615	236.6906	38.6398	-64.4308	-5198	-0.00068	-21.3378	-2310	-0.04488
	4.9680	6.4583	237.1873	39.0814	-60.4361	-4798	-0.00048	-19.5160	-2136	-0.04179
	4.9680	6.9551	237.6841	39.4496	-47.0121	-4451	-0.00017	-17.9485	-1987	-0.03808
	4.9680	7.4519	238.1809	39.7924	-44.0446	-4184	-0.0035	-16.5849	-1858	-0.03655
1600 1700 1800 1900 2000	4.9680	7.9487	238.6777	40.1130	-41.4480	-3894	-0.00051	-15.3871	-1745	-0.03433
	4.9680	8.4455	239.1745	40.4142	-36.1569	-3664	-0.00104	-14.2623	-1646	-0.03206
	4.9680	8.9423	239.6713	40.6981	-37.1208	-3450	-0.00126	-13.3708	-1558	-0.03000
	4.9680	9.4391	240.1681	40.9668	-35.2990	-3277	-0.00180	-12.5298	-1479	-0.02840
	4.9680	9.9359	240.6649	41.2216	-33.6577	-3112	-0.00220	-11.7619	-1408	-0.02682
2100 2200 2300 2400 2500	4.9680	10.4327	241.1617	41.4640	-32.1736	-2963	-0.00258	-11.0646	-1343	-0.02555
	4.9680	10.9235	241.6685	41.6851	-30.6242	-2827	-0.00327	-10.4283	-1286	-0.02440
	4.9680	11.4263	242.1653	41.9169	-29.5918	-2702	-0.00407	-9.8452	-1231	-0.02348
	4.9680	11.9231	242.6621	42.1273	-28.4610	-2588	-0.00480	-9.3068	-1183	-0.02220
	4.9680	12.4199	243.1489	42.3301	-27.4210	-2482	-0.00569	-8.8134	-1138	-0.02111
2600 2700 2800 2900 3000	4.9680	12.9167	243.6457	42.5250	-26.4616	-2384	-0.00674	-8.3546	-1097	-0.02010
	4.9680	13.4135	244.1426	42.7125	-25.5719	-2393	-0.00777	-7.9222	-1068	-0.01944
	4.9680	13.9103	244.6393	42.9932	-24.7492	-2298	-0.00892	-7.5309	-1023	-0.01844
	4.9680	14.4071	245.1361	43.0675	-23.9749	-2129	-0.00983	-7.1597	-990	-0.01770
	4.9680	14.9039	245.6329	43.2554	-23.2655	-2055	-0.01090	-6.8120	-959	-0.01695
3100 3200 3300 3400 3500	4.9680	15.4007	246.1297	43.3988	-22.5816	-1986	-0.01178	-6.4857	-930	-0.01638
	4.9680	15.8975	246.6265	43.5565	-21.9492	-1921	-0.01268	-6.1787	-903	-0.01588
	4.9680	16.3943	247.1233	43.7064	-21.3544	-1880	-0.01354	-5.8894	-878	-0.01500
	4.9680	16.8911	247.6201	43.8877	-20.7938	-1802	-0.01444	-5.6161	-854	-0.01440
	4.9680	17.3879	248.1169	44.0017	-20.2645	-1748	-0.01524	-5.3877	-831	-0.01397
3600 3700 3800 3900 4000	4.9680	17.8847	248.6137	44.1417	-19.7637	-1698	-0.01688	-5.1129	-810	-0.01348
	4.9680	18.3815	249.1106	44.2778	-19.2891	-1649	-0.01645	-4.8805	-790	-0.01291
	4.9680	18.8783	249.6073	44.4103	-18.8387	-1603	-0.01707	-4.6597	-771	-0.01231
	4.9680	19.3751	250.1041	44.5303	-18.4106	-1561	-0.01745	-4.4497	-753	-0.01198
	4.9680	19.8719	250.6009	44.6651	-18.0329	-1520	-0.01787	-4.2495	-736	-0.01149
4100 4200 4300 4400 4500	4.9680	20.3687	251.0977	44.7878	-17.6148	-1481	-0.01838	-4.0585	-720	-0.01097
	4.9680	20.8655	251.5945	44.9075	-17.2433	-1444	-0.01869	-3.8761	-705	-0.01045
	4.9680	21.3623	252.0913	45.0244	-16.8888	-1410	-0.01935	-3.7017	-690	-0.01008
	4.9680	21.8591	252.5881	45.1388	-16.5494	-1378	-0.01922	-3.5348	-675	-0.00968
	4.9680	22.3559	253.0849	45.2602	-16.2244	-1345	-0.01941	-3.3749	-663	-0.00927
4600 4700 4800 4900 5000	4.9680	22.8527	253.5817	45.3894	-15.9126	-1318	-0.01961	-3.2215	-650	-0.00890
	4.9680	23.3495	254.0785	45.4603	-15.6182	-1286	-0.01978	-3.0748	-639	-0.00838
	4.9680	23.8463	254.5753	45.5709	-15.3255	-1259	-0.01986	-2.9328	-626	-0.00814
	4.9680	24.3431	255.0721	45.6733	-15.0487	-1233	-0.01990	-2.7869	-616	-0.00770
	4.9680	24.8399	255.5689	45.7737	-14.7822	-1208	-0.01994	-2.6680	-605	-0.00737
5100 5200 5300 5400 5500	4.9680	25.3367	256.0657	45.8721	-14.5254	-1185	-0.01982	-2.5400	-595	-0.00708
	4.9680	25.8335	256.5625	45.9685	-14.2777	-1163	-0.01967	-2.4185	-586	-0.00672
	4.9680	26.3303	257.0593	46.0632	-14.0386	-1142	-0.01942	-2.3014	-576	-0.00638
	4.9680	26.8271	257.5561	46.1580	-13.8077	-1122	-0.01930	-2.1884	-568	-0.00593
	4.9680	27.3239	258.0529	46.2472	-13.5844	-1103	-0.01904	-2.0792	-558	-0.00576
5600 5700 5800 5900 6000	4.9680	27.8207	258.5497	46.3367	-13.3684	-1084	-0.01882	-1.9738	-550	-0.00551
	4.9680	28.3175	259.0465	46.4248	-13.1594	-1067	-0.01853	-1.8718	-541	-0.00532
	4.9680	28.8143	259.5433	46.5110	-12.9689	-1050	-0.01833	-1.7732	-534	-0.00499
	4.9680	29.3111	260.0401	46.5980	-12.7606	-1033	-0.01813	-1.6777	-526	-0.00473
	4.9680	29.8079	260.5369	46.6795	-12.5703	-----	-----	-1.5843	-----	-----

TABLE XXXVII—THERMODYNAMIC PROPERTIES OF
Li (GAS)

[Atomic weight, 6.940]

T (°K)	C_p^o (cal mole °K)	$H_f^o - H_0^o$ (kcal mole)	H_f^o (kcal mole)	S_f^o (cal mole °K)
0	—	0	166.6941	—
298.16	4.9680	1.4809	168.3750	33.1418
300	4.9680	1.4904	168.3845	33.1734
300	4.9680	1.4872	168.3818	34.6026
500	4.9680	2.4840	169.3781	35.7112
600	4.9680	2.9808	169.8749	36.6169
700	4.9680	3.4776	170.3717	37.3828
800	4.9680	3.9743	170.8684	38.0491
900	4.9680	4.4711	171.3652	38.6312
1000	4.9680	4.9679	171.8620	39.1547
1100	4.9680	5.4647	172.3588	39.6282
1200	4.9680	5.9615	172.8556	40.0605
1300	4.9681	6.4583	173.3524	40.4551
1400	4.9683	6.9551	173.8492	40.8263
1500	4.9685	7.4520	174.3461	41.1661
1600	4.9696	7.9489	174.8430	41.4998
1700	4.9711	8.4459	175.3400	41.7911
1800	4.9726	8.9432	175.8378	42.0763
1900	4.9735	9.4407	176.3348	42.3443
2000	4.9738	9.9388	176.8329	42.5908
2100	4.9908	10.4374	177.3315	42.8431
2200	5.0011	10.9370	177.8311	43.0755
2300	5.0142	11.4278	178.3319	43.2981
2400	5.0304	11.9190	178.8341	43.5119
2500	5.0506	12.4141	179.3382	43.7176
2600	5.0742	12.9033	179.8444	43.9162
2700	5.1017	13.4891	180.3532	44.1082
2800	5.1332	13.9709	180.8630	44.2943
2900	5.1657	14.4559	181.3800	44.4780
3000	5.2083	15.0048	181.8989	44.6509
3100	5.2520	15.5278	182.4219	44.8224
3200	5.2997	16.0564	182.9495	44.9899
3300	5.3497	16.5879	183.4820	45.1588
3400	5.4034	17.1255	184.0196	45.3143
3500	5.4619	17.6658	184.5529	45.4718
3600	5.5223	18.2180	185.1121	45.6265
3700	5.5841	18.7783	185.6674	45.7788
3800	5.6495	19.3350	186.2291	45.9284
3900	5.7152	19.9034	186.7975	46.0760
4000	5.7870	20.4756	187.3727	46.2217
4100	5.8686	21.0609	187.9550	46.3655
4200	5.9516	21.6504	188.5445	46.5075
4300	6.0053	22.2473	189.1414	46.6480
4400	6.0818	22.8516	189.7457	46.7869
4500	6.1576	23.4636	190.3577	46.9244
4600	6.2256	24.0832	190.9773	47.0608
4700	6.3129	24.7106	191.6047	47.1955
4800	6.3919	25.3489	192.2400	47.3293
4900	6.4702	25.9890	192.8831	47.4619
5000	6.5495	26.6400	193.5341	47.5934
5100	6.6275	27.2988	194.1929	47.7238
5200	6.7059	27.9655	194.8598	47.8533
5300	6.7833	28.6399	195.5340	47.9818
5400	6.8608	29.3222	196.2168	48.1098
5500	6.9373	30.0121	196.9062	48.2369
5600	7.0130	30.7096	197.6037	48.3616
5700	7.0890	31.4148	198.3087	48.4863
5800	7.1617	32.1271	199.0212	48.6102
5900	7.2345	32.8469	199.7410	48.7338
6000	7.3068	33.5740	200.4681	48.8558

TABLE XXXVIII—THERMODYNAMIC PROPERTIES OF LiF (GAS)

[Molecular weight, 25.940]

T (°K)	C_p (cal mole °K)	$H_f^0 - H_\infty^0$ (kcal mole)	H_f^0 (kcal mole)	S_f^0 (cal mole °K)	$\frac{\Delta H^\circ}{RT}$	$\delta \left(\frac{\Delta H^\circ}{RT} \right) = \frac{-\delta T}{100} \left(\frac{a+b}{T} \right)$	log K	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c+d}{T} \right)$		
								a	b	
0 298.16 300 400 500	7.0836 7.0872 7.3314 7.6048	0 2.0796 2.0926 2.8120	77.9204 80.0000 80.0130 80.7333	47.1209 47.1645 49.2249 50.9005	233.2688 231.8488 174.2249 139.7116		96.9757 95.4543 70.2551 55.1028			
600 700 800 900 1000	7.8484 8.0471 8.2042 8.3275 8.4245	4.3328 5.1280 5.9409 6.7677 7.6055	82.2532 88.0484 88.8613 84.6881 85.5259	52.3092 53.5345 54.6197 55.5935 56.4761	116.6880 100.1316 87.7402 78.0930 70.3683	6831 6981 6981 6981 6981	44.9810 37.7391 32.2995 28.0630 24.6694	3639 3639 3639 3639 3639	0.01707	
1100 1200 1300 1400 1500	8.5016 8.5685 8.6187 8.6349 8.6890	8.4518 9.3050 10.1639 11.0273 11.8945	86.3722 87.2264 88.0483 88.9477 89.8149	57.2828 58.0280 58.7124 59.3528 59.9506	64.0434 58.7692 58.3544 50.4741 47.1536	6306 5788 5444 4985 4687	0.01920 0.01660 0.01236 0.01050 0.00858	21.8896 19.5706 17.6083 15.9210 14.4589	2765 2386 2343 2177 2033	0.01483 .01353 .01173 .01077 .00988
1600 1700 1800 1900 2000	8.7175 8.7416 8.7621 8.7796 8.7948	12.7649 13.6378 14.5130 15.3901 16.2688	90.6883 91.5582 92.4334 93.3105 94.1892	60.5123 61.0416 61.5417 62.0159 62.4666	44.2400 41.6814 39.4002 37.3585 35.5207	4350 4086 3871 3669 3498	0.00668 0.00564 0.00438 0.00330 0.00215	18.1784 12.0476 11.0414 10.1405 9.3289	1607 1796 1697 1609 1529	0.00904 .00842 .00774 .00710 .00680
2100 2200 2300 2400 2500	8.8079 8.8194 8.8285 8.8384 8.8483	17.1489 18.0308 18.9128 19.7961 20.6804	95.0683 95.9507 96.8382 97.7165 98.6008	62.8961 63.3061 63.6983 64.0743 64.4383	33.8678 32.8456 30.9851 29.6996 28.5356	3824 3816 3804 2917 2803	0.00109 -.00037 -.00117 -.00280 -.00378	8.5940 7.9284 7.8144 6.7588 6.2376	1457 1392 1332 1277 1226	0.00633 .00578 .00560 .00540 .00520
2600 2700 2800 2900 3000	8.8534 8.8597 8.8653 8.8704 8.8760	21.5654 22.4510 23.3373 24.2241 25.1118	99.4585 100.3714 101.2577 102.1445 103.0317	64.7824 65.1146 66.4389 66.7501 66.0509	27.4613 26.4669 25.6440 24.8851 23.8841	2698 2602 2512 2429 2351	-.00496 -.00389 -.00731 -.00857 -.00969	5.7608 5.3189 4.9082 4.5255 4.1680	1179 1136 1095 1058 1023	0.00523 .00499 .00511 .00483 .00480
3100 3200 3300 3400 3500	8.8792 8.8830 8.8885 8.8897 8.8926	26.9990 26.8871 27.7756 28.6644 29.5536	103.9194 104.8075 105.6960 106.5848 107.4738	66.3420 66.6239 66.8973 67.1627 67.4204	23.1354 23.4340 21.7759 21.1672 20.5746	2279 2210 2146 2088 2030	-.01079 -.01160 -.01248 -.01397 -.01439	3.8332 3.5191 3.2237 2.9454 2.6327	990 959 930 908 877	0.00473 .00479 .00477 .00470 .00469
3600 3700 3800 3900 4000	8.8953 8.8978 8.9001 8.9022 8.9041	30.4420 31.3326 32.2225 33.1128 34.0029	108.3633 109.2530 110.1429 111.0330 111.9238	67.6710 67.9147 68.1590 68.3832 68.6057	20.0251 19.5061 19.0152 18.5004 18.1096	1975 2120 2146 2130 1787	-.01473 -.01563 -.01674 -.01670 -.01735	2.4344 2.1902 1.9762 1.7643 1.5627	852 829 807 788 768	0.00493 .00494 .00498 .00510 .00607
4100 4200 4300 4400 4500	8.9060 8.9076 8.9092 8.9107 8.9121	34.8834 35.7841 36.6749 37.5659 38.4571	112.8138 113.7045 114.5953 115.4863 116.3775	68.8286 69.0432 69.2528 69.4576 69.6579	17.6911 17.2936 16.9151 16.5448 16.2113	1745 1704 1678 1630 1596	-.01788 -.01788 -.01879 -.01873 -.01926	1.3708 1.1877 1.0762 1.0459 1.0260	748 729 712 698 680	0.00800 .00617 .00528 .00528 .00537
4600 4700 4800 4900 5000	8.9134 8.9146 8.9157 8.9168 8.9178	39.3484 40.2898 41.1813 42.0229 42.9146	117.2688 118.1602 119.0517 119.9433 120.8350	69.8538 70.0445 70.2332 70.4170 70.5972	15.8836 15.6707 15.2716 14.9855 14.7116	1561 1529 1497 1468 1437	-.01923 -.01944 -.01941 -.01970 -.01938	0.6328 0.5869 0.4449 0.3459 0.2026	666 651 636 623 611	0.00541 .00338 .00560 .00570 .00560
5100 5200 5300 5400 5500	8.9187 8.9196 8.9204 8.9212 8.9220	43.8084 44.6984 45.5004 46.4824 47.3746	121.7268 122.6188 123.5108 124.4028 125.2950	70.7738 70.9470 71.1169 71.2836 71.4474	14.4492 14.1977 13.9863 13.7247 13.5021	1409 1381 1355 1322 1308	-.01946 -.01917 -.01883 -.01855 -.01878	-0.1462 -0.1367 -0.1270 -0.1181 -0.1085	598 586 576 564 553	0.00580 .00583 .00592 .00595 .00606
5600 5700 5800 5900 6000	8.9227 8.9234 8.9240 8.9246 8.9252	48.2688 49.1591 50.0515 50.9439 51.8304	126.1872 127.0795 127.9719 128.8643 129.7568	71.6081 71.7661 71.9213 72.0798 72.2258	13.2882 13.0825 12.8444 12.6987 12.5100	1279 1255 1232 1209 1203	-.01869 -.01828 -.01811 -.01955 -.01934	-0.7091 -0.8104 -0.9085 -1.0084 -1.0954	543 534 524 515 511	0.00604 .00603 .00609 .00617 .00606

TABLE XXXIX—THERMODYNAMIC PROPERTIES OF LiH (GAS)

[Molecular weight, 7.948]

T (°K)	C _p (cal mole °K)	H _T —H ₀ (kcal mole)	H _T (kcal mole)	S _T (cal mole °K)	—ΔH° RT	s (—ΔH° RT) — $\frac{-\delta T}{100}(\frac{a}{T} + b)$		log K	s log K = $\frac{-\delta T}{100}(\frac{c}{T} + d)$	
						a	b		c	d
0 298.16	7.0763	0	190.8225	40.7663	105.9633	—	—	41.7055	—	—
	7.0797	2.0793	192.4018	40.8398	106.3228	—	—	41.4233	—	—
	7.0923	2.0923	192.4145	40.8398	106.3228	—	—	29.9651	—	—
	7.3175	2.8115	193.1340	42.9072	79.3373	—	—	23.0611	—	—
	7.6879	3.5568	193.8798	44.5692	63.7197	—	—	—	—	—
600 700 800 900 1000	7.8318	4.3281	194.6506	45.9748	53.2862	—	—	18.4412	—	—
	8.0312	5.1216	195.4441	47.1975	45.8178	—	—	15.1301	—	—
	8.1899	5.9330	196.2555	49.2807	40.2042	—	—	12.6394	—	—
	8.3145	6.7585	197.0810	48.2529	35.8319	—	—	10.6988	—	—
	8.4134	7.5951	197.9176	50.1842	32.3277	3136	0.0209	9.1388	1388	0.01598
1100 1200 1300 1400 1500	8.4918	8.4403	198.7628	50.9388	29.4507	2856	0.01550	7.8610	1284	0.01387
	8.5548	9.2927	199.6152	51.6814	27.0612	2621	0.01305	6.7938	1160	0.01260
	8.6060	10.1507	200.4732	52.3681	25.0820	2428	0.01019	5.8888	1072	0.01149
	8.6481	11.0134	201.3359	53.0074	23.2911	2252	0.00877	5.1116	997	0.01033
	8.6829	11.8899	202.2024	53.6053	21.7810	2104	0.00730	4.4366	932	0.00930
1600 1700 1800 1900 2000	8.7121	12.7497	203.0722	54.1668	20.4687	1975	0.00574	3.8448	875	0.00839
	8.7367	13.6221	203.9446	54.6955	19.2912	1861	0.00451	3.8217	824	0.00812
	8.7676	14.4989	204.8194	55.1955	18.2528	1759	0.00371	2.8558	780	0.00707
	8.7756	15.3735	205.6980	55.6694	17.3232	1669	0.00230	2.4382	739	0.00700
	8.7911	16.2518	206.5743	56.1200	16.4585	1588	0.00121	2.0617	703	0.00644
2100 2200 2300 2400 2500	8.8046	17.1816	207.4541	56.5492	15.7291	1514	0.00042	1.7205	670	0.00625
	8.8162	18.0127	208.3352	56.9891	15.0405	1448	—0.0087	1.4097	640	0.00604
	8.8266	18.8948	209.2173	57.8412	14.4118	1387	—0.0172	1.1254	613	0.00558
	8.8358	19.7779	210.1004	57.7270	13.8356	1332	—0.0280	.8644	583	0.00530
	8.8439	20.6519	210.9844	58.0879	12.3057	1282	—0.0428	.6239	565	0.00519
2600 2700 2800 2900 3000	8.8511	21.5487	211.8692	58.4349	12.8169	1235	—0.0511	0.4014	543	0.00519
	8.8576	22.4321	212.7546	58.7691	12.3646	1183	—0.0647	.1951	524	0.00486
	8.8634	23.3182	213.6407	59.0913	11.9450	1154	—0.0773	.0031	505	0.00456
	8.8686	24.2048	214.5273	59.4024	11.5348	1117	—0.0883	—1.759	495	0.00433
	8.8733	25.0918	215.4143	59.7032	11.1913	1083	—0.0975	—3.434	472	0.00414
3100 3200 3300 3400 3500	8.8776	25.9794	216.3019	59.9942	10.8517	1052	—0.01115	—0.5001	457	0.00459
	8.8815	26.8673	217.1898	60.2761	10.5341	1021	—0.0169	—.6477	443	0.00456
	8.8851	27.7557	218.0762	60.5495	10.2368	993	—0.0258	—.7845	429	0.00472
	8.8884	28.6444	218.9662	60.8148	9.9568	969	—0.0416	—.9174	417	0.00466
	8.8918	29.5333	219.8558	61.0724	9.6941	943	—0.0454	—1.0411	404	0.00473
3600 3700 3800 3900 4000	8.8941	30.4226	220.7451	61.3280	9.4467	918	—0.01491	—1.1581	394	0.00461
	8.8988	31.3121	221.6346	61.5887	9.2135	897	—0.01595	—1.2892	383	0.00481
	8.8990	32.2019	222.5244	61.8040	8.9934	877	—0.01687	—1.3746	373	0.00468
	8.9011	33.0919	223.4144	62.0382	8.7854	854	—0.01670	—1.4749	368	0.00475
	8.9032	33.9821	224.3046	62.2905	8.5886	836	—0.01760	—1.5704	354	0.00476
4100 4200 4300 4400 4500	8.9050	34.8726	225.1951	62.4804	8.4023	817	—0.01792	—1.6815	345	0.00488
	8.9068	35.7631	226.0856	62.6950	8.2287	796	—0.01808	—1.7455	336	0.00506
	8.9094	36.6539	226.9764	62.9046	8.0582	783	—0.01835	—1.8317	328	0.00505
	8.9099	37.5448	227.8678	63.1094	7.8991	765	—0.01880	—1.9113	321	0.00507
	8.9113	38.4395	228.7584	63.3097	7.7479	750	—0.01924	—1.9877	313	0.00526
4600 4700 4800 4900 5000	8.9126	39.3271	229.6496	63.5056	7.6041	733	—0.01906	—2.0610	306	0.00541
	8.9138	40.2184	230.5409	63.6972	7.4672	720	—0.01970	—2.1318	299	0.00541
	8.9150	41.1098	231.4323	63.8849	7.3389	704	—0.01947	—2.1990	292	0.00561
	8.9161	42.0014	232.3239	64.0688	7.2127	691	—0.01970	—2.2642	285	0.00570
	8.9171	42.8933	233.2156	64.2459	7.0842	673	—0.01926	—2.3269	279	0.00579
5100 5200 5300 5400 5500	8.9181	43.7848	234.1073	64.4255	6.9811	663	—0.01950	—2.3874	274	0.00581
	8.9190	44.6767	234.9992	64.5987	6.8721	649	—0.01935	—2.4459	257	0.00602
	8.9199	45.5686	235.8911	64.7886	6.7700	637	—0.01926	—2.5023	262	0.00598
	8.9207	46.4606	236.7831	64.9353	6.6714	624	—0.01905	—2.5568	257	0.00607
	8.9215	47.3527	237.6752	65.0960	6.5770	611	—0.01881	—2.6096	251	0.00628
5600 5700 5800 5900 6000	8.9222	48.2449	238.5674	65.2698	6.4867	599	—0.01859	—2.6607	247	0.00627
	8.9229	49.1372	239.4597	65.4177	6.4002	587	—0.01841	—2.7103	241	0.00645
	8.9236	50.0295	240.3520	65.5729	6.3174	576	—0.01823	—2.7582	236	0.00660
	8.9242	50.9219	241.2444	65.7254	6.2380	564	—0.01780	—2.8049	232	0.00663
	8.9248	51.8144	242.1369	65.8753	6.1618	—	—	—2.8502	—	—

TABLE XL—THERMODYNAMIC PROPERTIES OF N (GAS)

[Atomic weight, 14.008]

<i>T</i> (°K)	<i>C_p</i> (cal mole °K)	<i>H₂ - H₀</i> (kcal mole)	<i>H₂</i> (kcal mole)	<i>S₂</i> (cal mole °K)
0	4.9680	0	85.6696	—
298.16	4.9680	1.4812	87.4508	36.6145
300	4.9680	1.4904	87.4600	36.6450
400	4.9680	1.9872	87.9568	38.0742
500	4.9680	2.4840	88.4536	39.1828
600	4.9680	2.9808	88.9504	40.0885
700	4.9680	3.4776	89.4472	40.8544
800	4.9680	3.9744	89.9440	41.5177
900	4.9680	4.4712	90.4408	42.1029
1000	4.9680	4.9680	90.9376	42.6263
1100	4.9680	5.4648	91.4344	43.0998
1200	4.9680	5.9616	91.9312	43.5321
1300	4.9680	6.4584	92.4280	43.9297
1400	4.9680	6.9552	92.9248	44.2979
1500	4.9680	7.4520	93.4216	44.6406
1600	4.9680	7.9488	93.9184	44.9613
1700	4.9681	8.4456	94.4162	45.2625
1800	4.9681	8.9424	94.9120	45.5464
1900	4.9681	9.4392	95.4089	45.8151
2000	4.9680	9.9362	95.9058	46.0690
2100	4.9697	10.4331	96.4027	46.3124
2200	4.9708	10.9301	96.8997	46.5436
2300	4.9724	11.4273	97.3969	46.7816
2400	4.9746	11.9246	97.8942	46.9763
2500	4.9777	12.4222	98.3918	47.1794
2600	4.9816	12.9202	98.8888	47.3747
2700	4.9859	13.4186	99.3852	47.5628
2800	4.9835	13.9177	99.8873	47.7443
2900	5.0015	14.4174	100.3870	47.9197
3000	5.0108	14.9180	100.8876	48.0894
3100	5.0222	15.4197	101.3893	48.2539
3200	5.0354	15.9226	101.8922	48.4135
3300	5.0504	16.4258	102.3954	48.5687
3400	5.0675	16.9327	102.9023	48.7197
3500	5.0866	17.4404	103.4100	48.8669
3600	5.1079	17.9502	103.9198	49.0105
3700	5.1312	18.4621	104.4317	49.1608
3800	5.1567	18.9755	104.9461	49.2890
3900	5.1844	19.4885	105.4692	49.4222
4000	5.2143	20.0135	105.9881	49.5539
4100	5.2461	20.5365	106.5061	49.6830
4200	5.2800	21.0628	107.0294	49.8099
4300	5.3158	21.5926	107.5522	49.9345
4400	5.3533	22.1261	108.0857	50.0572
4500	5.3927	22.6634	108.6330	50.1770
4600	5.4335	23.2047	109.1743	50.2969
4700	5.4759	23.7502	109.7198	50.4142
4800	5.6197	24.2999	110.2695	50.5299
4900	5.6646	24.8424	110.8238	50.6442
5000	5.6109	25.4129	111.3825	50.7571
5100	5.6581	26.9764	111.9460	50.8687
5200	5.7063	26.5446	112.5142	50.9790
5300	5.7553	27.1177	113.0873	51.0832
5400	5.8052	27.6957	113.6653	51.1962
5500	5.8553	28.2788	114.2484	51.3092
5600	5.9070	28.8669	114.8365	51.4092
5700	5.9588	29.4602	115.4298	51.5142
5800	6.0114	30.0587	116.0283	51.6183
5900	6.0644	30.6625	116.6321	51.7216
6000	6.1179	31.2716	117.2412	51.8288

TABLE XLI—THERMODYNAMIC PROPERTIES OF N₂ (GAS)

[Molecular weight, 28.016]

T (°K)	C _s (cal mole °K)	H _T - H ₀ (kcal) mole	H _T (kcal) mole	S _T (cal mole °K)	$\frac{\Delta H^o}{RT}$	$\delta \left(\frac{-\Delta H^o}{RT} \right) = \frac{-\delta T}{100} \left(\frac{a}{T} + b \right)$	log K	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c}{T} + d \right)$			
								c	d		
0 238.16 300 400 500	0 6.960 6.961 6.961 7.070	0 2.0723 2.0851 2.7824 3.4850	1.6992 3.7716 3.7845 4.4816 5.1842	45.767 45.809 47.818 49.885	288.8283 297.0681 215.6725 172.8306	----- ----- ----- -----	119.4345 118.6656 87.4738 68.7269	----- ----- ----- -----	----- ----- ----- -----		
	800 700 800 900 1000	7.197 7.351 7.612 7.611 7.816	4.1980 4.9253 5.6636 6.4280 7.2025	50.685 51.805 52.797 53.692 54.809	144.2610 123.8438 108.5207 96.5987 87.0447	----- ----- ----- ----- 8865	56.2064 47.2492 40.5214 35.2815 31.0841	----- ----- ----- 3768 3768	----- ----- ----- 0.02405		
	1100 1200 1300 1400 1500	7.947 8.063 8.165 8.233 8.330	7.9907 8.7912 9.8026 10.4235 11.2526	9.6899 10.4904 11.3018 12.1227 12.9518	55.2801 55.9685 56.6080 57.2143 57.7863	19.2255 72.7044 67.1823 62.4456 58.3377	7790 7145 6600 6133 5727	0.02943 0.02694 0.02241 0.01923 0.01732	27.6455 24.7786 22.8465 20.2614 18.4626	3418 3188 2998 2693 2615	
	1600 1700 1800 1900 2000	8.399 8.459 8.512 8.560 8.602	12.0501 12.9320 13.7805 14.6341 15.4922	13.7833 14.6312 15.4797 16.3333 17.1914	58.3261 58.8371 59.3221 59.7836 60.2287	54.7410 51.5656 48.7414 48.2132 43.9887	5373 5060 4781 4532 4308	0.01481 0.01309 0.01188 0.01050 0.00927	16.8684 15.4694 14.2247 13.1101 12.1063	2380 2228 2101 1991 1893	
	2100 2200 2300 2400 2500	8.640 8.674 8.705 8.733 8.759	16.8543 17.2200 18.0890 18.9609 19.8355	18.0536 18.9192 19.7882 20.6801 21.5347	60.8443 61.0471 61.4333 61.8044 62.1614	41.8760 40.0019 38.2901 38.7204 35.2769	4105 3921 3763 3599 3487	0.00819 0.00702 0.00595 0.00490 0.00419	11.1973 10.3703 9.6147 8.9216 8.2335	1804 1728 1649 1581 1519	
2600 2700 2800 2900 3000	8.783 8.805 8.8253 8.8440 8.8610	20.7126 21.6920 22.4735 23.3570 24.2422	22.4118 22.2012 24.1727 25.0562 25.9414	62.5054 62.8373 63.1579 63.4678 63.7680	33.9421 32.7069 31.5598 30.4916 29.4947	3827 3207 3096 2992 2896	0.00298 0.00174 0.00061 -0.00043 -0.00169	7.6940 7.1479 6.6104 6.1677 5.7261	1461 1407 1357 1311 1268	0.00309 0.00500 0.00477 0.00460 0.00327	
	3100 3200 3300 3400 3500	8.8774 8.8928 8.9073 8.9210 8.9340	25.1291 26.0177 26.9077 27.7991 28.6918	26.5233 26.8209 26.6069 26.4983 26.3910	64.0588 64.3409 64.6148 64.8809 65.1307	28.5622 27.6880 26.8671 26.0947 25.3667	2806 2722 2644 2570 2501	-0.00268 -0.00174 -0.00025 -0.00023 -0.00772	5.3128 4.9260 4.5805 4.2172 3.8933	1227 1189 1153 1120 1088	0.00436 0.00420 0.00418 0.00390 0.00388
	3600 3700 3800 3900 4000	8.9462 8.9577 8.9656 8.9790 8.9890	29.6586 30.4810 31.3773 32.2747 33.1781	31.2850 32.1802 33.0766 33.9739 34.8723	65.3915 65.6968 65.8768 66.1069 66.3364	24.6797 24.0301 23.4153 22.8326 22.2795	2436 2375 2317 2262 2210	-0.00673 -0.01020 -0.01140 -0.01240 -0.01362	3.5872 3.2074 3.0227 2.7618 2.5128	1088 1029 1002 975 952	0.00385 0.00391 0.00398 0.00400 0.00380
	4100 4200 4300 4400 4500	8.9987 9.0082 9.0174 9.0263 9.0350	34.0725 34.0729 35.8741 36.7763 37.6794	35.7717 36.6721 37.5733 38.4765 39.3786	66.5585 66.7764 66.9875 67.1949 67.3979	21.7541 21.2544 20.7877 20.3253 19.8928	2160 2112 2068 2026 1984	-0.01459 -0.01570 -0.01680 -0.01772 -0.01840	2.2777 2.0527 1.8379 1.6327 1.4365	928 906 885 864 845	0.00405 0.00410 0.00408 0.00420 0.00420
	4600 4700 4800 4900 5000	9.0435 9.0518 9.0600 9.0681 9.0780	38.5833 39.4581 40.3987 41.3001 42.2073	40.2826 41.1873 42.0929 42.9983 43.9065	67.5965 67.7911 68.6818 68.1987 69.3520	19.4790 19.0653 18.7031 18.3470 18.0012	1945 1907 1870 1825 1801	-0.01923 -0.02009 -0.02089 -0.02120 -0.02184	1.2496 1.0855 .8987 .7298 .5703	827 809 792 775 759	0.00414 0.00426 0.00427 0.00450 0.00448
5100 5200 5300 5400 5500	9.0838 9.0915 9.0991 9.1068 9.1140	45.1163 46.0791 47.0320 48.0483 49.7549	44.8145 50.2783 51.1916 52.1055 53.2109	68.5318 69.5446 68.8815 69.0516 69.2188	17.6399 16.9427 17.0472 16.7514 16.4731	1768 1694 1706 1677 1648	-0.02220 -0.02284 -0.02313 -0.02381 -0.02369	0.4170 2.2693 1.1270 0.7298 -0.1426	744 729 714 700 686	0.00462 0.00475 0.00498 0.00513 0.00530	
	5600 5700 5800 5900 6000	9.1214 9.1287 9.1359 9.1431 9.1502	47.6666 48.5791 49.4924 50.4083 51.3210	49.3658 50.2783 51.1916 52.1055 53.0202	69.3881 69.5446 68.8815 69.0516 69.2188	16.2027 16.9427 17.0472 16.7514 16.4731	1620 1694 1706 1677 1648	-0.02421 -0.02483 -0.02507 -0.02507 -0.02410	0.2704 -.3839 -0.6290 -0.637 -0.7410	673 661 645 637 622	0.00543 0.00533 0.00577 0.00553 0.00533

TABLE XLII—THERMODYNAMIC PROPERTIES OF NO (GAS)

[Molecular weight, 30.008]

T (°K)	C _p cal (mole °K)	H ₂ ^o -H ₂ ^o (kcal) (mole)	H ₂ ^o (kcal) (mole)	S ₂ cal (mole °K)	$\frac{\Delta H^o}{RT}$	$\delta \left(-\frac{\Delta H^o}{RT} \right) - \frac{\delta T}{100} \left(\frac{a}{T} + b \right)$	log K	$\delta \log K = \frac{\delta T}{100} \left(\frac{c}{T} + d \right)$	
								a	b
0	7.187	0	23.3447	25.4389	207.8039	-----	-----	84.8403	-----
298.16	7.187	2.1942	25.4389	25.5515	204.5399	-----	-----	84.2976	-----
300	7.184	2.2068	25.5515	25.584	165.2832	-----	-----	61.8373	-----
400	7.183	2.0208	25.2855	25.436	124.5126	-----	-----	48.3348	-----
500	7.289	3.4440	26.7887	26.048	-----	-----	-----	-----	-----
600	7.488	4.3812	27.7259	26.902	103.9835	-----	-----	39.3132	-----
700	7.657	5.1336	28.4818	26.556	89.3049	-----	-----	32.8556	-----
800	7.833	5.9098	29.2443	27.589	73.2839	-----	-----	28.0035	-----
900	7.990	6.7005	30.0462	28.520	69.7015	-----	-----	24.2228	-----
1000	8.126	7.5060	30.8507	29.3700	62.8276	6160	0.03030	21.1087	2707
1100	8.248	8.3245	31.6692	30.1500	57.1974	5606	0.02667	18.7115	2465
1200	8.342	9.1637	32.4984	30.8715	52.5009	5143	.02155	16.6401	2262
1300	8.426	9.9921	33.3368	31.5425	48.5232	4751	.01873	14.8861	2090
1400	8.493	10.8383	34.1890	32.1696	45.1109	4415	.01637	13.3759	1943
1500	8.560	11.6912	35.0369	32.7580	42.1512	4124	.01410	12.0721	1815
1600	8.614	12.5499	35.8946	33.3122	39.5596	3869	0.01232	10.9274	1708
1700	8.660	13.4136	36.7683	33.8348	37.2714	3844	.01086	9.9162	1604
1800	8.702	14.2817	37.6264	34.3319	35.2861	3444	.00937	9.0165	1516
1900	8.738	15.1587	38.4884	34.8034	33.4141	3285	.00830	8.2107	1427
2000	8.771	16.0292	39.8739	35.2524	31.7733	3104	.00711	7.4548	1367
2100	8.801	16.9078	40.2825	35.6811	30.2881	2958	0.00616	6.8274	1202
2200	8.828	17.7892	41.1339	36.0912	28.9374	2826	.00520	6.2248	1244
2300	8.852	18.6732	42.0179	36.4841	27.7085	2704	.00473	5.8826	1191
2400	8.874	19.5995	42.9042	36.8613	26.5721	2593	.00410	5.1811	1142
2500	8.895	20.4480	43.7927	37.2240	25.5308	2491	.00332	4.7193	1097
2600	8.914	21.3384	44.6831	37.5732	24.5604	2393	0.00235	4.2927	1056
2700	8.932	22.2307	45.5754	37.9100	23.6789	2311	.00154	3.8873	1017
2800	8.949	23.1248	46.4695	38.2361	22.8520	2230	.00103	3.5299	981
2900	8.966	24.0205	47.3652	38.5494	22.0820	2156	.00013	3.1875	948
3000	8.981	24.9179	48.2626	38.8337	21.3632	2086	-.00060	2.8677	910
3100	8.996	26.8167	49.1614	39.1484	20.6909	2021	-.00138	2.5683	887
3200	9.010	26.7170	50.0617	39.4342	20.0607	1961	-.00224	2.2874	850
3300	9.024	27.6187	50.9634	39.7117	19.4687	1904	-.00310	2.0233	834
3400	9.037	28.5218	51.8663	39.9918	18.9118	1851	-.00386	1.7745	810
3500	9.049	28.4261	52.7708	39.2434	18.3368	1800	-.00450	1.5397	787
3600	9.061	30.3316	53.6763	40.4935	17.8913	1752	-.00528	1.3178	765
3700	9.073	31.2383	54.5830	40.7449	17.4228	1708	-.00597	1.1077	745
3800	9.085	32.1462	55.4909	40.9901	16.9798	1666	-.00658	.9985	726
3900	9.096	33.0552	56.3993	41.2282	16.5588	1628	-.00740	.7194	707
4000	9.107	33.9654	57.3101	41.4556	16.1597	1588	-.00812	.5395	689
4100	9.118	34.8706	58.2213	41.6806	15.7805	1562	-.00872	3.3682	672
4200	9.128	35.7839	59.1336	41.9005	15.4197	1518	-.00952	2.2050	656
4300	9.138	36.7022	60.0469	42.1154	15.0762	1488	-.01000	.0492	641
4400	9.148	37.6135	60.9612	42.3296	14.7487	1453	-.01039	-.0937	627
4500	9.158	38.5318	61.8765	42.5312	14.4362	1422	-.01063	-.2422	612
4600	9.168	39.4451	62.7928	42.7326	14.1377	1393	-.01108	-.3784	599
4700	9.178	40.3664	63.7101	42.9209	13.8524	1365	-.01148	-.6092	586
4800	9.188	41.2837	64.6284	43.1232	13.5795	1332	-.01176	-.8146	574
4900	9.198	42.2030	65.5477	43.3128	13.3182	1313	-.01220	-.7561	561
5000	9.208	43.1233	66.4680	43.4987	13.0678	1288	-.01255	-.8708	550
5100	9.218	44.0446	67.3803	43.6912	12.8278	1264	-.01298	539	0.00355
5200	9.227	44.9669	68.3116	43.8802	12.5974	1240	-.01326	528	0.00308
5300	9.237	45.8901	69.2348	44.0361	12.3762	1218	-.01366	517	0.00390
5400	9.246	46.8142	70.1589	44.2088	12.1637	1196	-.01415	507	0.00392
5500	9.256	47.7303	71.0840	44.3786	11.9594	1175	-.01432	507	0.00405
5600	9.266	48.6654	72.0101	45.5454	11.7629	1155	-.01453	497	0.00409
5700	9.275	49.5925	72.9372	46.7095	11.5738	1136	-.01486	478	0.00429
5800	9.285	50.5208	73.8652	47.8709	11.3918	1117	-.01512	469	0.00441
5900	9.294	51.4494	74.7941	48.0297	11.2161	1099	-.01537	461	0.00447
6000	9.304	52.3793	75.7240	48.1860	11.0469	1081	-.01562	453	0.00452

TABLE XLIII—THERMODYNAMIC PROPERTIES OF O (GAS)

[Atomic weight, 16.0000]

T (°K)	C_v^o (cal mole °K)	$H_f^o - H_0^o$ (kcal mole)	H_f^o (kcal mole)	S_f^o (cal mole °K)
0	—	0	59.6041	—
298.16	5.2364	1.6074	61.2115	38.4689
300	5.2238	1.6170	61.2211	38.5010
400	5.1341	2.1349	61.7390	39.9915
500	5.0802	2.6454	62.2495	41.1308
600	5.0456	3.1517	62.7558	42.0540
700	5.0284	3.6555	63.2598	42.8307
800	5.0150	4.1576	63.7617	43.5011
900	5.0055	4.6587	64.2628	44.0914
1000	4.9888	5.1588	64.7629	44.6183
1100	4.9636	5.6584	65.2625	45.0945
1200	4.9394	6.1576	65.7617	45.6288
1300	4.9064	6.6564	66.2605	45.9281
1400	4.8838	7.1549	66.7590	46.2975
1500	4.8618	7.6532	67.2578	46.6413
1600	4.8405	8.1513	67.7564	46.9628
1700	4.9792	8.6493	68.2554	47.2646
1800	4.9784	9.1471	68.7512	47.5492
1900	4.9778	9.6450	69.2491	47.8184
2000	4.9776	10.1427	69.7468	48.0737
2100	4.9778	10.6405	70.2446	48.3166
2200	4.9784	11.1383	70.7424	48.5451
2300	4.9796	11.6362	71.2403	48.7695
2400	4.9812	12.1343	71.7384	48.9814
2500	4.9834	12.6325	72.2366	49.1848
2600	4.9862	13.1310	72.7351	49.3903
2700	4.9897	13.6298	73.2339	49.5986
2800	4.9935	14.1289	73.7320	49.7901
2900	4.9986	14.6285	74.2326	49.9224
3000	5.0041	15.1287	74.7328	50.0650
3100	5.0102	15.6294	75.2335	50.2592
3200	5.0170	16.1207	75.7248	50.4183
3300	5.0245	16.6228	76.2269	50.5728
3400	5.0325	17.1257	76.7288	50.7229
3500	5.0411	17.6393	77.2244	50.8689
3600	5.0502	18.1439	77.7240	51.0111
3700	5.0599	18.6494	78.2235	51.1496
3800	5.0700	19.1559	78.7200	51.2846
3900	5.0805	19.6634	79.2275	51.4165
4000	5.0914	20.1720	79.7761	51.5482
4100	5.1026	20.6817	80.2858	51.6711
4200	5.1140	21.1925	80.7966	51.7942
4300	5.1257	21.7045	81.3038	51.9147
4400	5.1375	22.2177	81.8218	52.0326
4500	5.1495	22.7320	82.3361	52.1452
4600	5.1616	23.2476	82.8517	52.2415
4700	5.1738	23.7644	83.3685	52.3727
4800	5.1860	24.2824	83.8855	52.4911
4900	5.1981	24.8016	84.4037	52.5388
5000	5.2102	25.3220	84.9261	52.6639
5100	5.2223	25.8436	85.4477	52.7972
5200	5.2344	26.3664	85.9705	52.8988
5300	5.2464	26.8905	86.4948	52.9936
5400	5.2583	27.4157	87.0198	53.0948
5500	5.2701	27.9421	87.5462	53.1933
5600	5.2818	28.4697	88.0738	53.2884
5700	5.2933	28.9955	88.6026	53.3820
5800	5.3047	29.5224	89.1325	53.4742
5900	5.3159	30.0504	89.6635	53.5649
6000	5.3270	30.5916	90.1957	53.6544

TABLE XLIV—THERMODYNAMIC PROPERTIES OF O₂ (GAS)

[Molecular weight, 32.000]

T (°K)	C _p (cal mole °K)	H _P - H _D (kcal mole)	H _P (kcal mole)	S _P (cal mole °K)	ΔH° RT	$s \left(\frac{\Delta H^o}{RT} - \frac{\delta T}{100} \left(\frac{a}{T} + b \right) \right)$	log K [*]	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c}{T} + d \right)$	
								c	d
0 268.16	7.031	0	2.0362	49.011	189.6335	-----	-----	80.6182	-----
	7.023	2.0876	4.1109	49.056	198.4695	-----	-----	80.0367	-----
	7.196	2.7977	4.1238	51.098	149.2819	-----	-----	58.5109	-----
	7.431	3.5288	5.5650	52.728	119.7013	-----	-----	45.5311	-----
	7.670	4.2841	6.3203	54.105	99.9669	-----	-----	36.8580	-----
600	7.853	5.0620	7.0582	55.303	85.5610	-----	-----	30.6499	-----
800	8.063	5.8596	7.8958	56.368	75.2496	-----	-----	25.9854	-----
900	8.212	6.6737	8.7099	57.327	66.9087	-----	-----	22.3515	-----
1000	8.336	7.5012	9.5374	58.1900	60.3812	5928	0.02858	19.4400	2804
1100	8.439	8.3400	10.3762	59.9983	54.0654	5392	0.02417	17.0845	2370
1200	8.527	9.1883	11.2245	59.7384	50.4479	4947	0.02061	15.0640	2178
1300	8.604	10.0448	12.0810	60.4220	46.8219	4569	0.01873	13.3777	2009
1400	8.674	10.9087	12.9449	61.0622	42.8306	4245	0.01700	11.9307	1867
1600	8.738	11.7793	13.8155	61.6628	40.4926	3963	0.01642	10.6752	1744
1800	8.800	12.6562	14.6924	62.2287	37.9908	3717	0.01523	9.5756	1637
1700	8.858	13.5391	15.5763	62.7640	35.7976	3499	0.01501	8.6044	1542
1800	8.916	14.4278	16.4640	63.2719	33.8787	3305	0.01473	7.7403	1468
1900	8.973	15.3228	17.8685	63.7585	32.0845	3132	0.01420	6.9665	1383
2000	9.029	16.2224	18.2586	64.2172	30.8043	2976	0.01386	6.2695	1315
2100	9.084	17.1280	19.1642	64.6590	29.0783	2835	0.01356	5.6384	1253
2200	9.139	18.0392	20.0754	65.0829	27.7711	2707	0.01324	5.0643	1197
2300	9.194	18.9558	20.9920	65.4904	26.5809	2680	0.01283	4.5898	1146
2400	9.248	19.8779	21.9141	65.8828	25.4989	2484	0.01200	4.0588	1099
2500	9.301	20.8054	22.8416	66.2614	24.4833	2386	0.01161	3.6187	1056
2600	9.354	21.7781	23.7743	66.6272	23.5540	2295	0.01120	3.2066	1018
2700	9.405	22.7611	24.7123	66.9812	22.6928	2212	0.01080	2.8277	980
2800	9.455	23.6191	25.6553	67.3241	21.8922	2135	0.00979	2.4756	945
2900	9.503	24.5670	26.6032	67.6568	21.1462	2063	0.00913	2.1477	913
3000	9.551	25.5197	27.5859	67.9797	20.4494	1997	0.00881	1.8415	883
3100	9.596	26.4770	28.5182	68.2936	19.7969	1935	0.00761	1.5550	855
3200	9.640	27.4388	29.4780	68.5990	19.1846	1877	0.00671	1.2862	828
3300	9.682	28.4049	30.4411	68.8963	18.6091	1822	0.00622	1.0337	804
3400	9.723	29.3752	31.4114	69.1859	18.0670	1771	0.00540	.7980	781
3500	9.762	30.3494	32.3856	69.4683	17.5536	1723	0.00469	.5718	759
3600	9.799	31.3275	33.3837	69.7439	17.0723	1677	0.00426	0.3600	739
3700	9.835	32.3092	34.8454	70.0128	16.6148	1634	0.00380	0.1595	719
3800	9.869	33.2044	35.8306	70.2756	16.1813	1594	0.00278	-0.0304	700
3900	9.901	34.2829	36.8191	70.5282	15.7698	1555	0.00226	-0.2106	682
4000	9.932	35.2745	37.3107	70.7834	15.3738	1519	0.00161	-0.3818	665
4100	9.960	36.2691	38.3053	71.0290	15.0067	1484	0.00107	-0.5447	649
4200	9.987	37.2665	39.3027	71.2698	14.6523	1450	0.00069	-0.6999	634
4300	10.018	38.2685	40.3027	71.5046	14.3144	1419	0.00010	-0.8479	619
4400	10.037	39.2690	41.3052	71.7531	13.9918	1388	-0.00014	-0.9892	608
4500	10.060	40.2738	42.3100	71.9609	13.6935	1359	-0.00063	-1.1243	592
4600	10.081	41.2809	43.3171	72.1822	13.3887	1331	-0.00089	-1.2535	579
4700	10.103	42.3001	44.3263	72.3993	13.1084	1304	-0.00127	-1.3772	567
4800	10.121	43.3018	45.3375	72.6122	12.8360	1279	-0.00162	-1.4958	556
4900	10.139	44.3148	46.3605	72.8210	12.5768	1254	-0.00190	-1.6096	543
5000	10.166	45.3290	47.3862	73.0261	12.3277	1230	-0.00208	-1.7188	533
5100	10.172	46.3454	48.3816	73.2278	12.0886	1207	-0.00232	-1.8238	522
5200	10.187	47.3634	49.3996	73.4250	11.8588	1184	-0.00240	-1.9248	512
5300	10.201	48.3828	50.4190	73.6192	11.6378	1162	-0.00248	-2.0220	502
5400	10.215	49.4036	51.4398	73.8100	11.4281	1143	-0.00262	-2.1188	493
5500	10.228	50.4237	52.4619	73.9975	11.2261	1122	-0.00286	-2.2058	484
5600	10.239	51.4496	53.4858	74.1819	11.0226	1102	-0.00293	-2.2928	475
5700	10.250	52.4736	54.5097	74.3682	10.8322	1084	-0.00310	-2.3768	466
5800	10.261	53.4991	55.5353	74.5416	10.6483	1067	-0.00335	-2.4579	458
5900	10.270	54.3256	56.5616	74.7171	10.4709	1049	-0.00343	-2.5363	450
6000	10.279	55.5531	57.5893	74.8898	10.2995	-----	-0.6121	-----	-----

TABLE XLV—THERMODYNAMIC PROPERTIES OF OH (GAS)

[Molecular weight, 17.008]

T (°K)	C_p (cal mole °K)	$H_f - H_0$ (kcal mole)	H_f (kcal mole)	S_f (cal mole °K)	$\frac{\Delta H^\circ}{RT}$	$\delta \left(\frac{\Delta H^\circ}{RT} \right) = \frac{-\delta T}{100} \left(\frac{a+b}{T} \right)$	log K'	$\delta \log K = \frac{-\delta T}{100} \left(\frac{c+d}{T} \right)$	
								c	d
0 298.16	7.141	0	44.7286	43.888	170.7527	-----	-----	69.3677	-----
	2.1062	48.8328	48.8328	43.984	169.7395	-----	-----	68.9110	-----
	7.139	2.1225	46.8491	45.978	127.6916	-----	-----	50.4585	-----
	7.074	2.8298	47.5862	47.5858	102.4572	-----	-----	39.3522	-----
	7.048	3.5350	48.2616	47.558	-----	-----	-----	-----	-----
600 700 800 900 1000	7.053	4.2408	48.9674	48.840	85.6303	-----	-----	31.9260	-----
	7.087	4.9469	49.6735	49.927	73.6091	-----	-----	26.6057	-----
	7.150	5.6584	50.3850	50.877	64.5888	-----	-----	22.6043	-----
	7.234	6.3774	51.1040	51.723	57.5862	-----	-----	19.4838	-----
	7.333	7.1060	51.8328	52.4910	51.9464	5034	0.02814	16.9801	2227
1100 1200 1300 1400 1500	7.440	7.8446	52.5712	53.1949	47.3419	4575	0.02930	14.9267	2029
	7.551	8.5942	53.3208	53.8470	43.1001	4194	0.02915	13.2113	1863
	7.663	9.3549	54.0815	54.4559	40.2448	3573	0.02777	11.7665	1723
	7.772	10.1286	54.8532	55.0278	37.4506	3599	0.02607	10.5067	1603
	7.876	10.9090	55.6368	55.6575	35.0252	3361	0.02478	9.4213	1498
1600 1700 1800 1900 2000	7.973	11.7014	56.4280	56.0758	32.8998	3153	0.02340	8.4697	1407
	8.066	12.5033	57.2299	56.6650	31.0217	2970	0.02210	7.5285	1327
	8.152	13.3142	58.0408	57.0285	29.3496	2808	0.02041	6.8793	1255
	8.233	14.1335	58.8601	57.4714	27.8513	2863	0.01890	6.2079	1190
	8.308	14.9605	59.6371	57.8956	26.8009	2533	0.01731	5.8027	1133
2100 2200 2300 2400 2500	8.378	15.7948	60.5214	58.3027	25.2774	2415	0.01617	5.0542	1080
	8.443	16.6359	61.3626	58.6339	24.1636	2308	0.01482	4.5549	1032
	8.504	17.4832	62.2098	59.0705	22.1452	2210	0.01387	4.0983	989
	8.561	18.3265	63.0631	59.4237	22.2105	2121	0.01260	3.6792	949
	8.614	19.1952	63.9218	59.7842	21.3495	2038	0.01185	3.2931	912
2600 2700 2800 2900 3000	8.663	20.0591	64.7857	60.1230	20.5538	1982	0.01093	2.8963	878
	8.710	20.9277	65.6543	60.4508	19.8162	1892	0.00999	2.6065	846
	8.755	21.8010	66.6276	60.7684	19.1305	1826	0.00884	2.2979	817
	8.798	22.6786	67.4052	61.0764	18.4915	1765	0.00811	2.0113	790
	8.833	23.5604	68.2870	61.8753	17.8944	1708	0.00813	1.7434	764
3100 3200 3300 3400 3500	8.877	24.4462	69.1728	61.6858	17.6358	1635	0.00741	1.4926	740
	8.918	25.3387	70.0623	61.9482	16.8107	1605	0.00694	1.2572	716
	8.949	26.2288	70.9554	62.2230	16.3174	1558	0.00646	1.0359	697
	8.982	27.1253	71.8519	62.4906	15.8527	1513	0.00621	.8273	677
	9.015	28.0282	72.7518	62.7515	15.4142	1471	0.00579	.6306	659
3600 3700 3800 3900 4000	9.047	28.9283	73.6549	63.0059	14.9998	1432	0.00527	0.4445	641
	9.077	29.8345	74.5811	63.2542	14.6075	1395	0.00459	.2984	624
	9.107	30.7437	75.4708	63.4968	14.2355	1359	0.00461	.1014	608
	9.135	31.6568	76.3824	63.7336	13.8824	1325	0.00435	-.0572	593
	9.162	32.5706	77.2972	63.9552	13.5468	1288	0.00413	-.2080	579
4100 4200 4300 4400 4500	9.189	33.4882	78.2148	64.1917	13.2273	1263	0.00379	-0.3516	565
	9.215	34.4084	79.1350	64.4135	12.9223	1224	0.00352	-4.884	552
	9.241	35.3312	80.0578	65.0306	12.6923	1206	0.00331	-6.1910	538
	9.266	36.2585	80.8831	65.8434	12.3549	1179	0.00320	-7.437	528
	9.290	37.1843	81.0109	65.0318	12.0897	1144	0.00303	-8.890	517
4600 4700 4800 4900 5000	9.314	38.1145	82.8411	65.2563	11.8368	1129	0.00239	-0.9772	506
	9.338	39.0471	83.7787	65.4569	11.6927	1106	0.00283	-1.0866	495
	9.362	39.9821	84.7057	65.6837	11.3596	1084	0.00253	-1.1915	485
	9.394	40.9194	85.6460	65.8470	11.1353	1062	0.00260	-1.2922	476
	9.406	41.8539	86.6335	66.0368	10.9208	1041	0.00243	-1.3890	466
5100 5200 5300 5400 5500	9.427	42.8006	87.5272	66.2283	10.7143	1021	0.00235	-1.4820	458
	9.448	43.7443	88.4709	66.4065	10.5156	1002	0.00214	-1.5715	449
	9.469	44.6902	89.4168	66.5867	10.3244	984	0.00208	-1.6678	440
	9.489	45.6381	90.3647	66.7639	10.1401	966	0.00206	-1.7408	433
	9.509	46.5830	91.3148	66.9382	9.9824	949	0.00194	-1.8209	425
5600 5700 5800 5900 6000	9.529	47.5399	92.2665	67.1097	9.7910	922	0.00189	-1.8962	418
	9.548	48.4937	93.2208	67.2785	9.6286	916	0.00187	-1.9728	411
	9.567	49.4495	94.1781	67.4447	9.4683	901	0.00179	-2.0449	404
	9.585	50.4071	95.1337	67.6084	9.3113	886	0.00163	-2.1146	397
	9.603	51.3665	96.0931	67.7697	9.1620	-----	-2.1820	-----	-----